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TELEMETER DESIGN PARAMETERS FOR NIKE APACHES 14.171 GE - 14.176 GE

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"Telemeter Design Parameters for

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ABSTRACT

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This report covers the design philosophy and operational performance evaluation of the telemeter system for Nike Apache sounding rockets 14.171 GE through 14.176 GE. Data are included in Appendices A and B to allow the reader to make final measurements on components of each payload telemeter and notes for setting up and checking out the entire system. Design and performance evaluation for these telemeter systems were conducted by GSFC's Sounding Rocket Instrumentation Section personnel. Included are preliminary flight results indicating that these systems performed as predicted and that good experimental data is expected.

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NIKE APACHES 14.171 GE - 14.176 GE

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SUMMARY

This report covers the design philosophy and operational performance evaluation of the telemetry system for Nike Apache sounding rockets 14.171 GE through 14.176 GE. Included in Appendix A are final measurements made on components of each payload telemeter, which were used to verify performance through hard-wire or RF link checks. Appendix B contains notes for setting up and checking out the entire system. Design and performance evaluation for these telemeter systems was conducted by GSFC's Sounding Rocket Instrumentation Section personnel.

Preliminary flight results indicate that these systems performed as predicted and that good experimental data can be expected.

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INTRODUCTION

This document was first assembled as a reference guide for checkout and verification of the telemeter system which was to be flown on Nike Apaches 14.171 GE through 14.176 GE. These payloads (Figure 1) were launched from the Mobile Launch Facility during its South American cruise in March and April 1965 (see Report on Mobile Launch Expedition Number 1, Volume II, 671-65-166). Subsequent to the successful shipboard launchings, these data were reorganized into this more formal report, to be used as documentary information relative to these flights, and as reference material for an additional series of similar payloads in the planning stages.

Design philosophy and operational performance evaluation of the telemetry system for this series of Nike Apache rockets (prior to payload launchings), is covered in this report. Actual flight performance has not been evaluated other then a cursory assessment that all objectives appear to have been met. Appendix A contains the final measurements made on components of each rocket telemeter system. Appendix B provides additional comments on set-up and checkout procedures.

BACKGROUND

The original objective of the scientific payloads for Nike Apaches 14.171 GE through 14.176 GE was to measure the current distribution within the equatorial electrojet in the vicinity of the magnetic dip equator, using rubidium magnetometer techniques. Subsequently, a secondary exploratory experiment was included to measure voltages induced on isolated probes. Firings were scheduled from the Mobile Launch Facility between Panama and Lima, Peru.

Principal payload components included the magnetometer and its associated oscillator, amplifier, heaters, and thermocouples (for preheating and monitoring the magnetometer temperature from external sources through the umbilical); the telemeter system and its 45°, swept-back, turnstile antenna; and a power distribution system. A DOVAP transponder was also included for trajectory information, operating through shroud antennas strapped to the Apache motor case.

These payloads were generally similar to those successfully flown on Nike Apaches 14.155 GE through 14.159 GE from Wallops Island during the summer of 1964 (see Instrumentation Report on

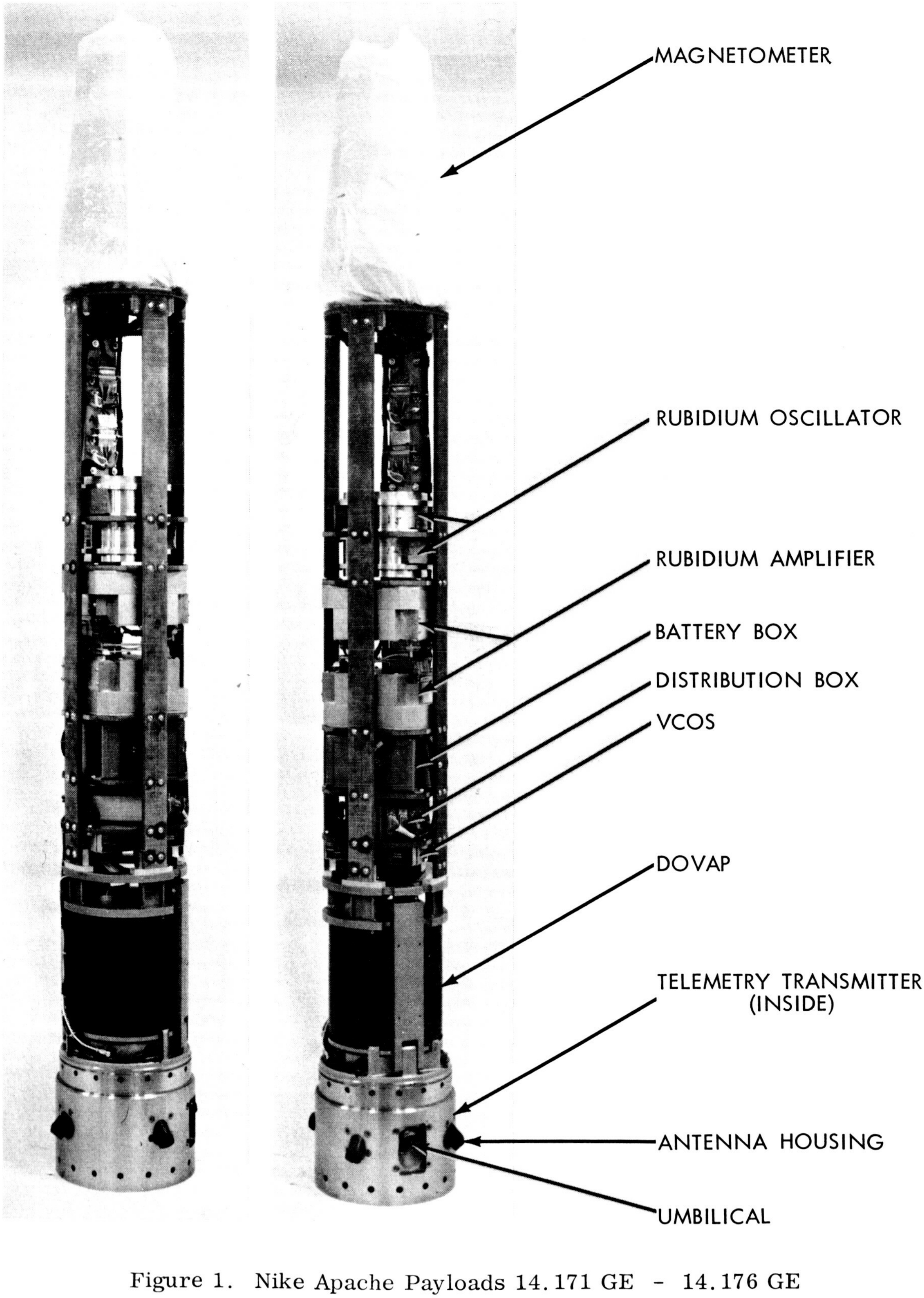

Figure 1. Nike Apache Payloads 14.171 GE - 14.176 GE

Nike Apaches 14.155 GE through 14.159 GE, X-671-64-303). Major differences were (a) the present series employed a two-cell rubidium magnetometer in lieu of the single cell flown previously, and (b) the expected magnetometer output frequency would be in the range of 160 ±80 kc/s. Due to differences in magnetic field with latitude, this signal was somewhat lower than the 250 kc/s developed during integration tests at GSFC and the previous Wallops Island launchings.

Project scientists for both series were Drs. J. Heppner, T. N. Davis, and Mr. J. Stolarik.

Special telemetry transmitters were obtained by Sounding Rocket Instrumentation Section for these payloads. In addition to being made as nearly non-magnetic as practical, transmitter modulation characteristics were modified to yield a reasonably constant (±1 db) deviation sensitivity over the range of 160 ±80 kc/s. No restrictions were specified for frequencies outside this range, since the magnetometer signal was the only data to be transmitted at the time this order was placed. As a result, the low frequency modulation sensitivity was very poor.

With the addition of the electrometer probe experiment by Dr. T. Aggson, various modifications had to be made in the telemetry system configuration. Input probes for Dr. Aggson's data were made available by converting the telemeter transmitting antenna from a phased, right-hand circularly-polarized, four-element turnstile, to a linearly-phased, two-element dipole. The two unused elements then became the input probes for the electrometers. Outputs from the electrometers were fed to three, low-frequency, voltage-controlled oscillators and multiplexed with the magnetometer signal. Highest data frequencies from this experiment were associated with the vehicle spin rate, and were, therefore, not expected to exceed 12 c/s.

Nike Apache payload 14.160 GE, held over from the previous Wallops Island launchings, was included with the shipboard launchings. It was not modified to incorporate Dr. Aggson's experiment.

TRANSMITTER

	SPECIFICATIONS
Manufacturer	Vector Manufacturing Co.
Model No.	TRFP-2VA (non-magnetic)
RF Link	231.4 mc/s
RF Power Output	2 watts minimum

SPECIFICATIONS (Con't)

Carrier Stability	0.005%
Carrier Deviation	±125 kc/s nominal
Modulation	Phase-modulated
Modulation Sensitivity	See Figures 2 through 9
Power Input	24 to 38 vdc, 800 ma nominal

BANDWIDTH

The rf carrier bandwidth of this telemetry system was appreciably wider than a normal IRIG rf link. A practical rule-of-thumb for estimating bandwidth of any FM system, which takes into consideration the importance of the first several sidebands and the normal roll-off characteristic of receiver IF amplifier, is:

$$BW = 2(f_m + \Delta f)$$

where f_m = highest modulating frequency
and Δf = maximum carrier deviation.

In the present case where:

f_m = 240 kc/s
and Δf = 125 kc/s

the total carrier bandwidth would approach 730 kc/s. To faithfully copy this signal, receivers should have an IF bandwidth of approximately 750 kc/s. A wider IF bandwidth would unduly penalize the system signal-to-noise ratio (SNR), without contributing significantly to improve signal fidelity. A narrower IF bandwidth could have been used with some SNR improvement, at the expense of a more distorted signal waveform, and more critical receiver tuning. High frequency components would have been affected the most, since it is their side bands that would not be passed by the IF amplifiers.

On these present payloads, the nominal magnetometer signal at 160 kc/s was an order of magnitude higher in frequency than the highest voltage-controlled subcarrier oscillator (VCO) frequency. Therefore, with partially limited receiver bandwidth, distortion of the magnetometer signal could be expected to occur first, with little or no distortion of the VCO multiplex signal, unless the receiver could not be tuned properly. With a 500 kc/s IF bandwidth, the magnetometer signal waveform would have become triangular. However, since the information conveyed by these data was in the frequency of the signal, and not in its amplitude nor waveshape, this amount of distortion could be tolerated and still produce the proper frequency count. IF bandwidths less than 500 kc/s were not recommended for this system.

RF POWER

A 1/4-watt telemetry transmitter is normally sufficient for the slant ranges achieved by Nike Apaches with a standard IRIG telemeter system. This power was considered marginal for these magnetometer payloads because of the high modulating frequencies expected and the extra bandwidth requirements which result. Two-watt transmitters (the next-higher power transmitter used by Sounding Rocket Instrumentation Section), were consequently selected. Actual power output from these transmitters ranged between 3 and 5 watts at 30 volts input and at room temperature, degrading somewhat at high temperatures.

Similar 2-watt transmitters performed quite well on the previous series (14.155 GE through 14.159 GE), except for 14.158 GE, where a vehicle anomaly was accompanied by a complete loss of the rf link. On the other launchings, no rf signal dropouts were noted until after the payload turned over on reentry. Signal strength at apogee was in the vicinity of 30 to 50 microvolts. Results from the present series were comparable.

DEVIATION

With the addition of three VCO's for Dr. Aggson's experiment, transmitter modulation characteristics, as originally specified, were no longer suitable, and were altered by Sounding Rocket Instrumentation Section personnel. Modifications consisted of reshaping the roll-off characteristics of the modulator circuits, on a cut-and-try basis, until a satisfactory response was obtained. Two different procedures were used, depending on:

(a) how the unit was originally wired. Vector hand-tailors each transmitter by connecting trimming resistors to various stand-offs, as required. It was not known what parameter each resistor controlled.

(b) how a particular transmitter responded to a simple circuit change, and

(c) how much time was available to trim the transmitter response to all specifications.

The simpler approach, consisting of removing a peaking choke and substituting a high frequency roll-off condenser and sensitivity resistor, worked on five of the six new transmitters. One of the new series and the two spares from the previous series, did not respond to this treatment. They required the addition of a low-Q, series-resonant, L-R circuit to simultaneously bring in the low and high-frequency ends. With the latter units, no workable circuit could be found to reduce the deviation sensitivity down to the desired levels in the time available. Consequently, the deviation sensitivity on these three transmitters was greater than the others and required less drive from the mixer amplifier.

Modulation characteristics for all eight transmitters, as modified, are shown in Figures 2 through 9. Design objectives were to develop ±125 kc/s carrier deviation from a 5-volt, peak-to-peak, 160 kc/s modulation input signal. Deviation was required to be constant within ±1 db over the frequency range of 160 ±80 kc/s, with a gradual roll-off to a linear, phase-modulated characteristic down to low frequencies.

Three sets of data were taken. The two solid curves show 1- and 5-volt, peak-to-peak, sinusoidal signals applied directly to the transmitter modulation input. The dashed curve is a 1-volt, peak-to-peak input to a Vector TA-58A mixer amplifier, whose gain was adjusted to give ±125 kc/s deviation at 160 kc/s. Deviation was measured from the peak-to-peak video output of an FM receiver (750 kc/s IF), as displayed by an oscilloscope, when the receiver video gain had been calibrated to produce 5 volts peak-to-peak for a deviation of ± 125 kc/s. The noise threshold for the system was roughly 34 db below ±125 kc/s deviation.

The 1- and 5-volt curves show a substantially constant difference of 14 db (voltage ratio of 5 = 14 db) from which it can be inferred that the transmitters had no appreciable amplitude non-linearities over these modulation input levels, and that the receiver bandwidth was adequate to at least the peak response point. Curves for other modulation input levels were calculated and are shown as additional dashed curves in the low frequency region.

Transmitter serial numbers 453, 455, 457, 459, and 462 were modified by the condenser roll-off method and were shunted down to give the desired ±125 kc/s deviation at 160 kc/s, 5-volt peak-to-peak modulation input. Consequently, there is little difference between the direct and mixer amplifier curves in the low frequency end. Differences in the high frequency range were caused principally by working the mixer amplifier near its high frequency limit. For the majority of these transmitters, the peak point came out somewhat higher in frequency after the modifications were packaged in the transmitter than it had been when the components were tacked in during initial adjustment. The magnitude of this shift did not compromise the systsm's performance in any measureable way.

Transmitter serial number 460 from the new series, and serial numbers 356 and 359, left over spares from the previous series, were modified by the series choke method, with no practical adjustment of deviation sensitivity feasible. Excessive deviations were obtained when the transmitter was driven directly at 5 volts peak-

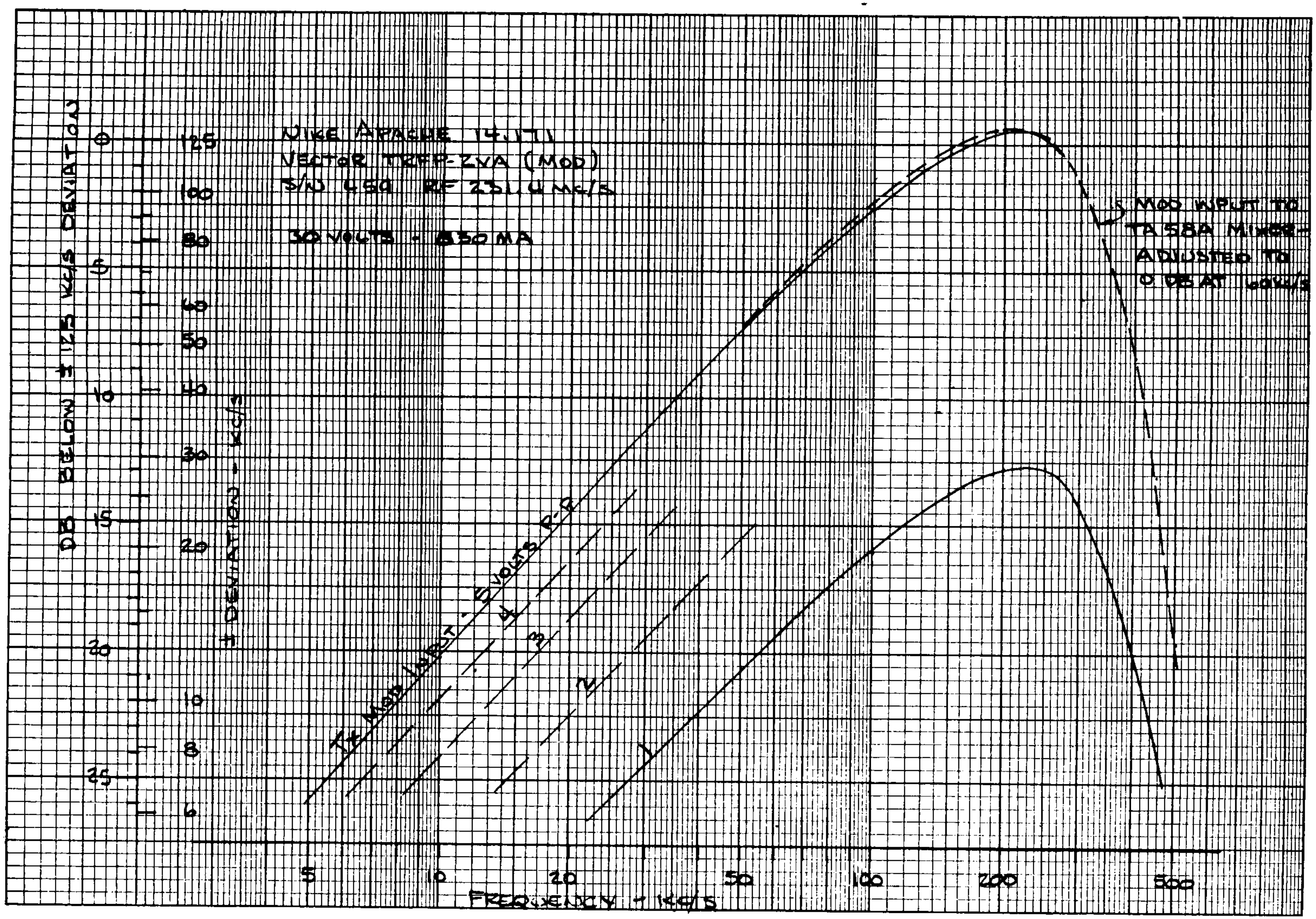

Figure 2. Nike Apache 14.171 GE Transmitter Deviation Characteristics

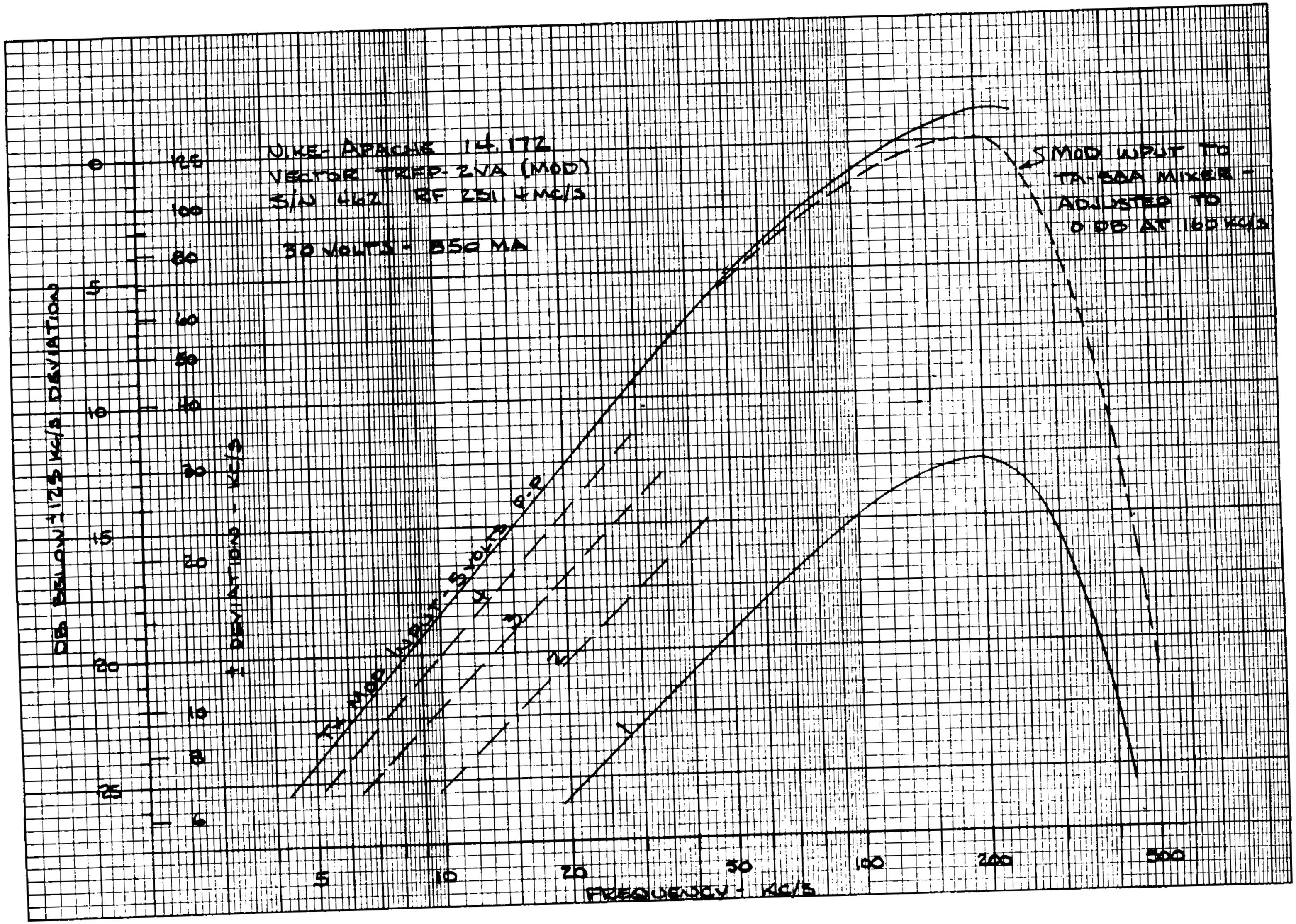

Figure 3. Nike Apache 14.172 GE Transmitter Deviation Characteristics

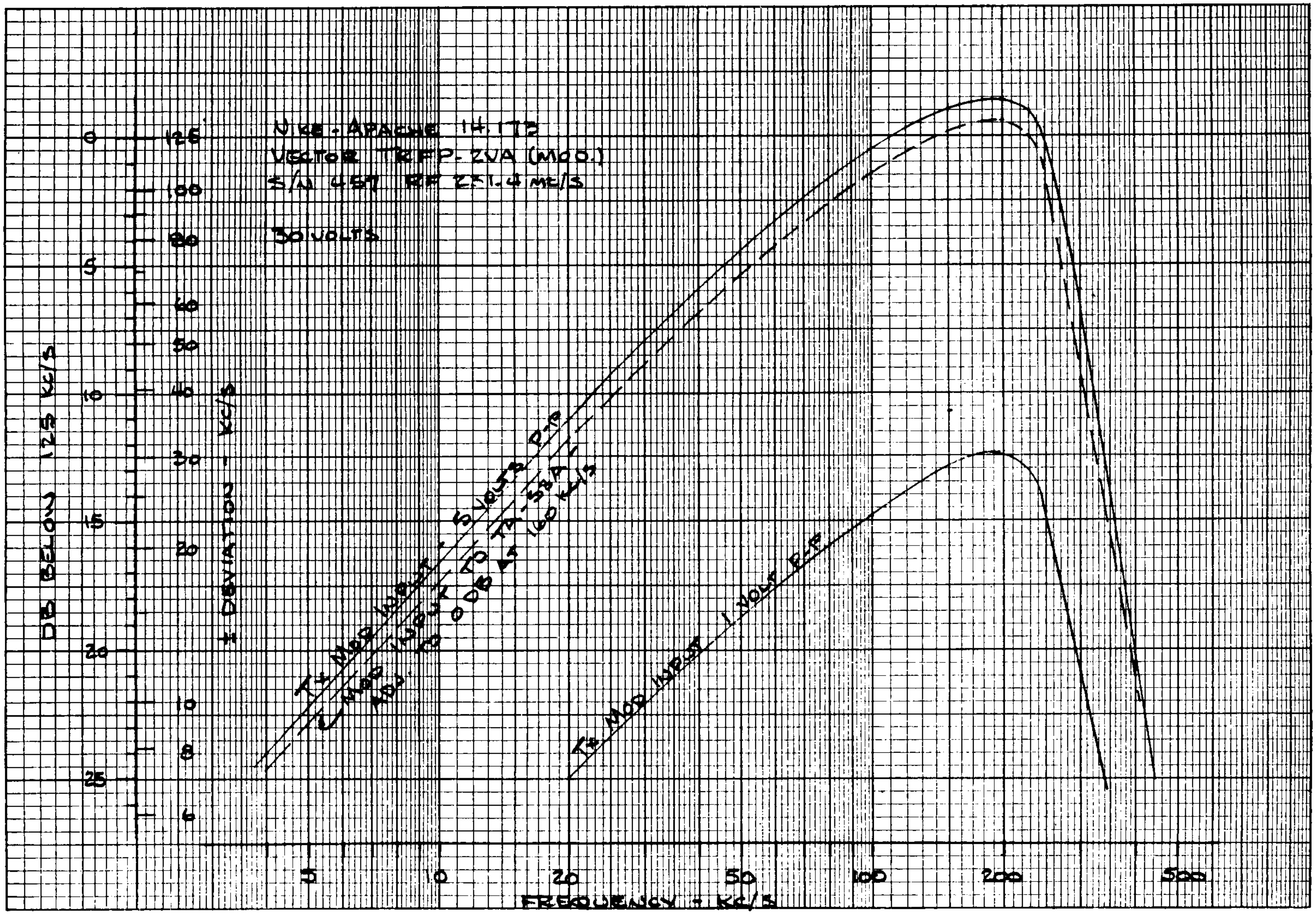

Figure 4. Nike Apache 14.173 GE Transmitter Deviation Characteristics

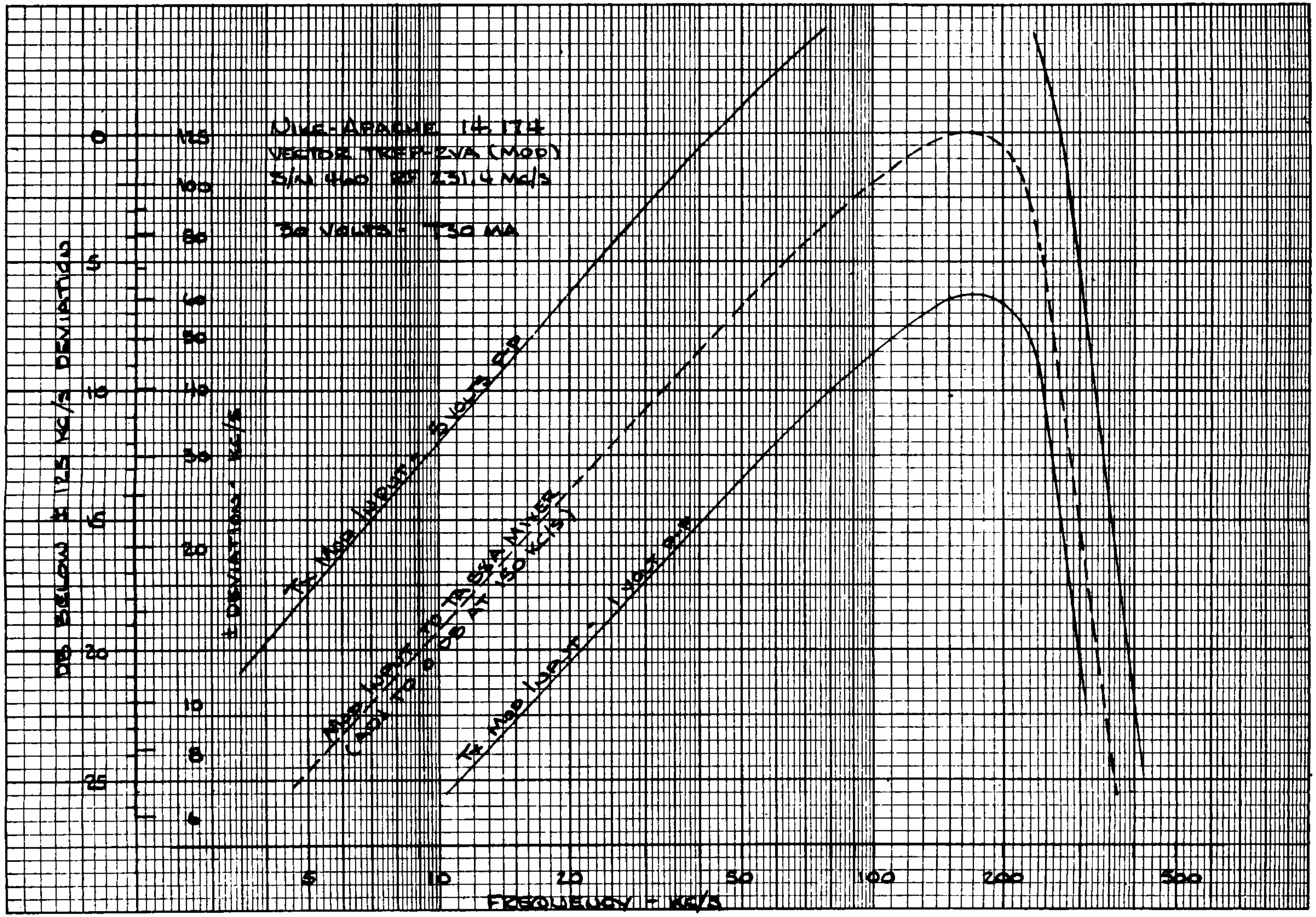

Figure 5. Nike Apache 14.174 GE Transmitter Deviation Characteristics

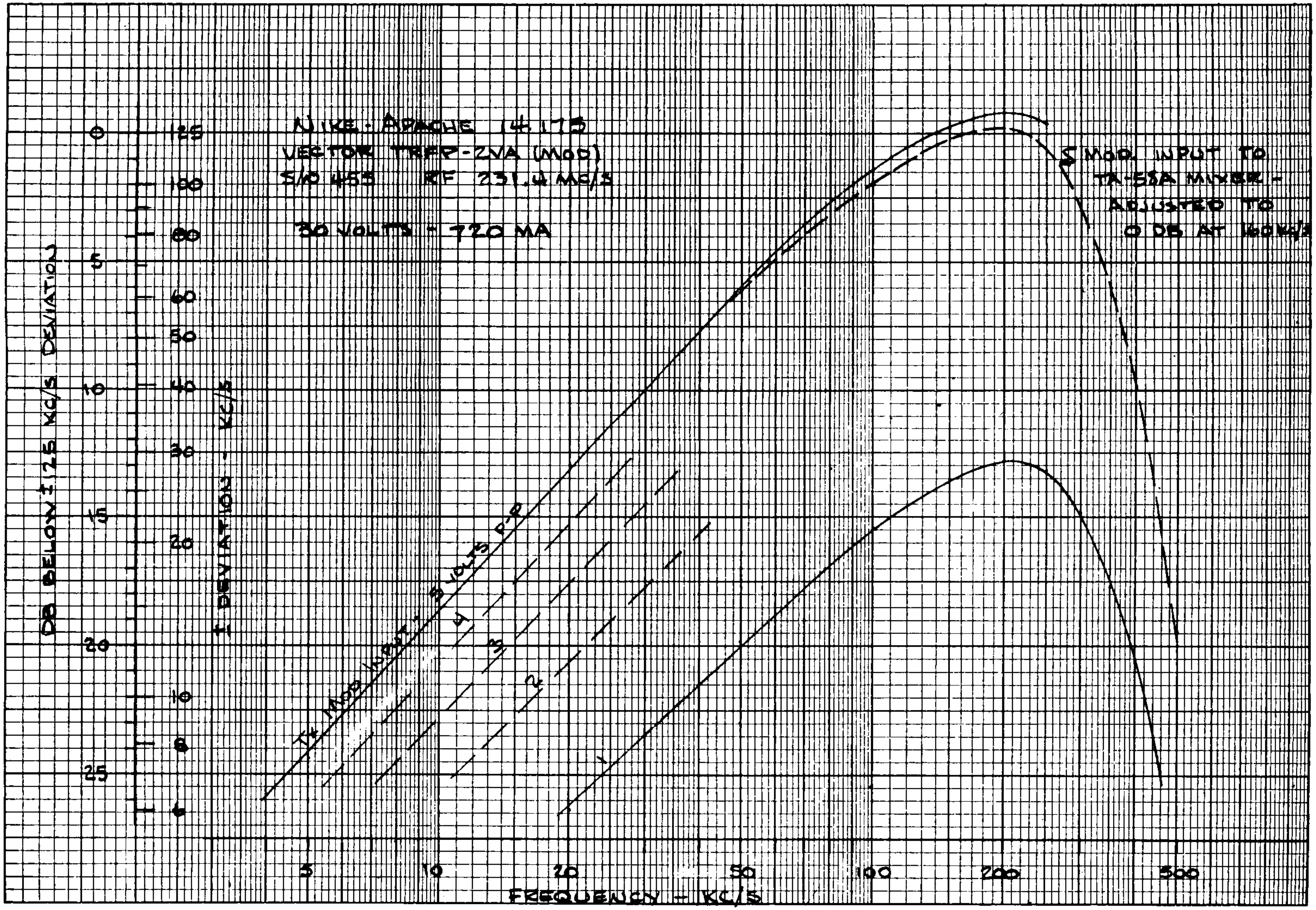

Figure 6. Nike Apache 14.175 GE Transmitter Deviation Characteristics

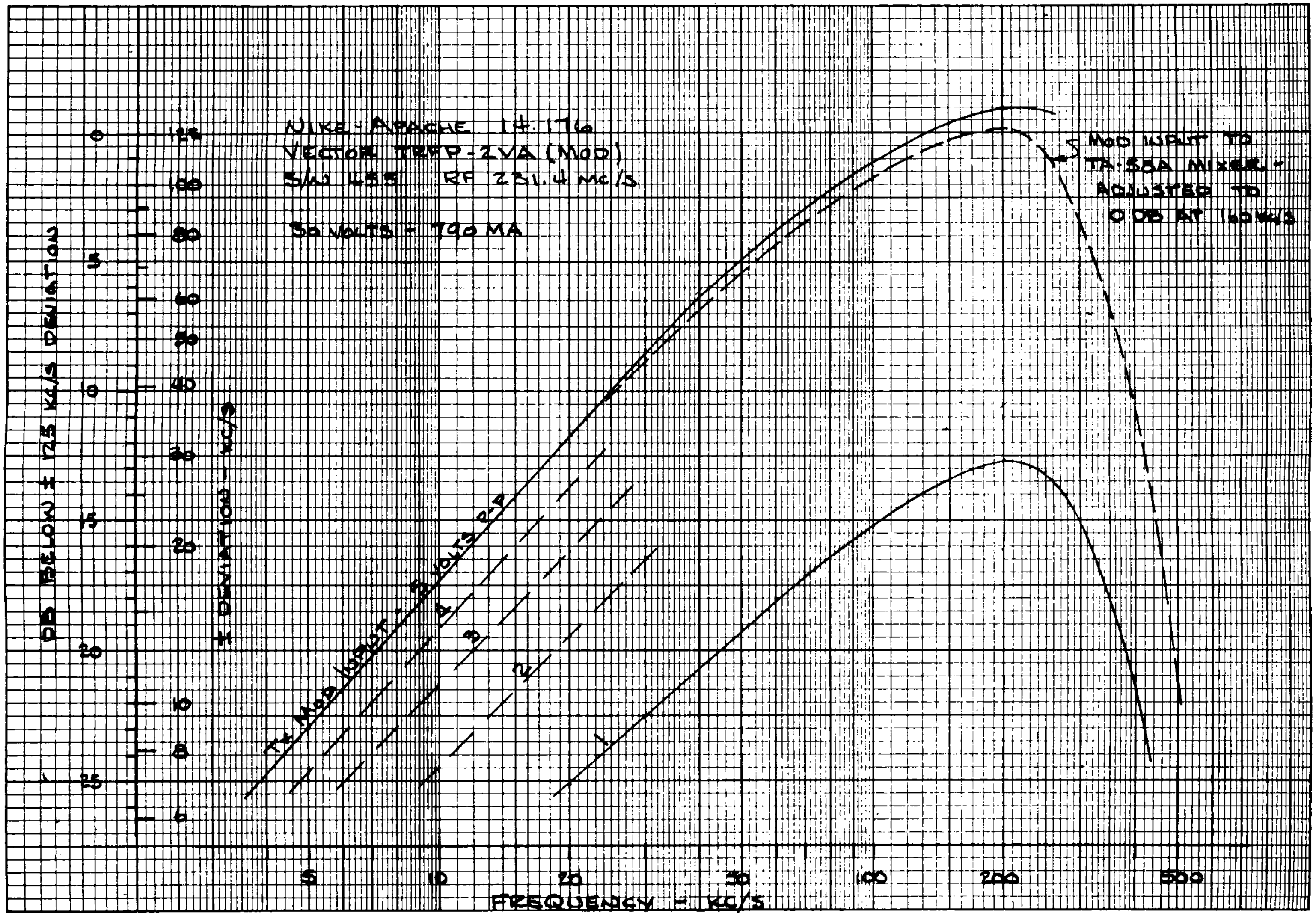

Figure 7. Nike Apache 14.176 GE Transmitter Deviation Characteristics

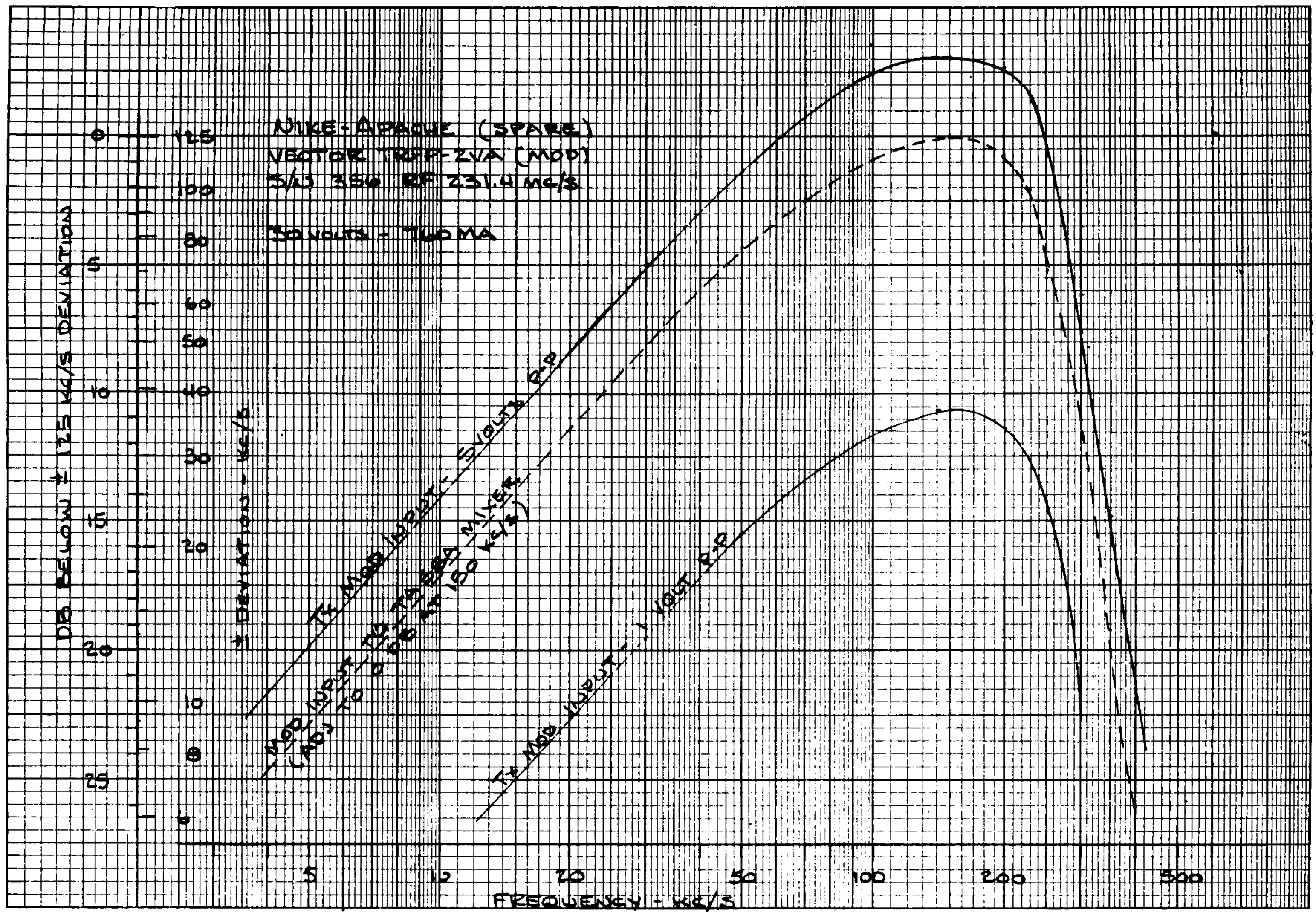

Figure 8. Nike Apache Spare #1 Transmitter Deviation Characteristics

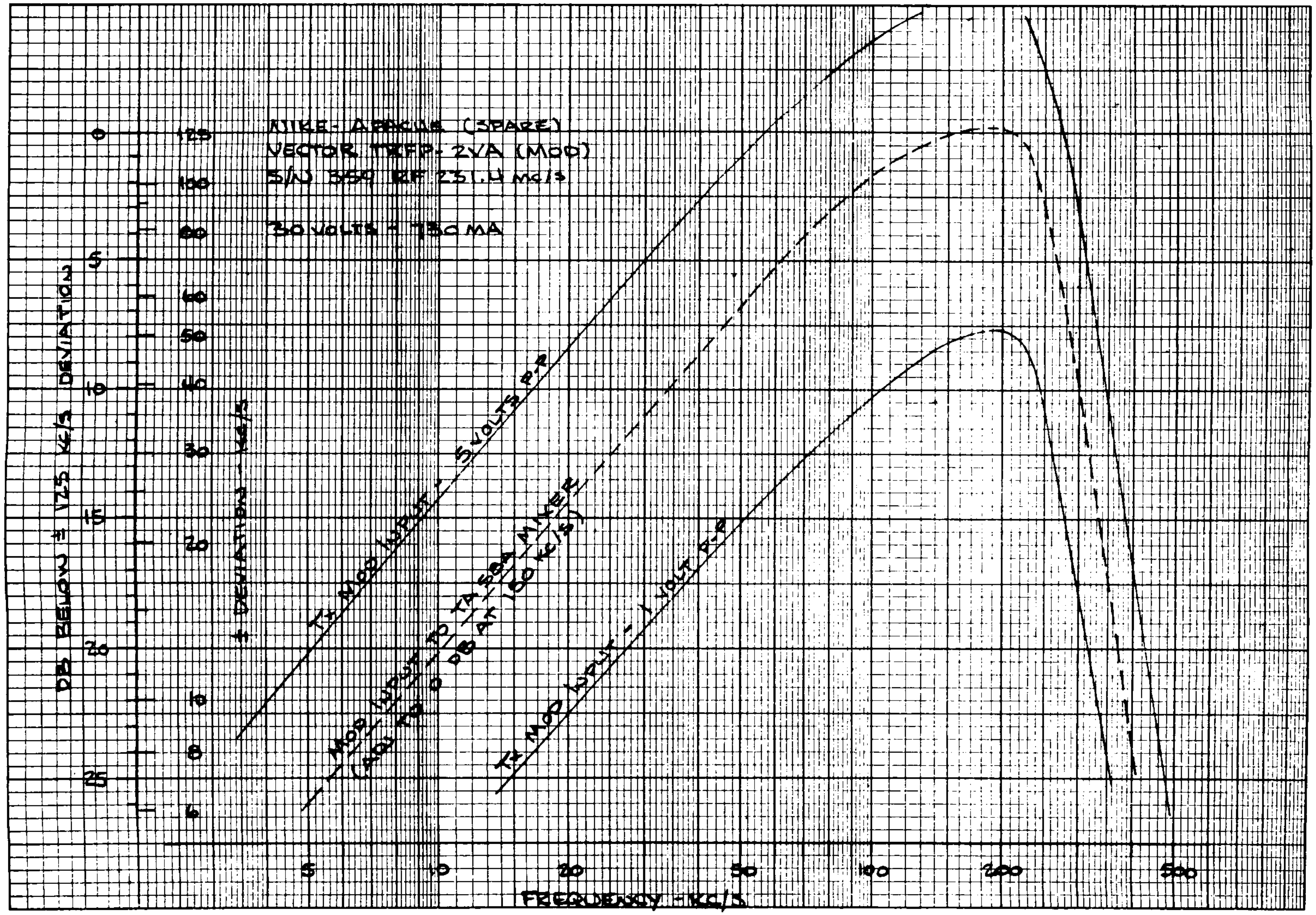

Figure 9. Nike Apache Spare #2 Transmitter Deviation Characteristics

to-peak. With the mixer amplifier adjusted to the reference level, the response of these transmitters were essentially identical to the others. This difference only became evident when the payload was checked internally, and showed up only as a lower drive level to the transmitter modulation input.

SUBCARRIER MULTIPLEX SYSTEM

SPECIFICATIONS

(a) VCO's

Manufacturer	Vector Manufacturing Co.
Model No.	TS-54A
Frequencies	14.5 kc/s, Band 13 10.5 kc/s, Band 12 7.35 kc/s, Band 11
Deviation	All ±7.5%
Data Input Voltage	0 to +5 volts
Input Impedance	1 megohm ±20%
Input Power	24 to 38 vdc, 10 ma nominal

(b) Mixer Amplifiers

Manufacturer	Vector Manufacturing Co.
Model No.	TA-58A
Frequency Range	300 c/s to 100 kc/s, ±0.5 db
Gain	Variable to X 15
Maximum Output	10 volts peak-to-peak
Input Impedance	10K ohms
Input Power	24 to 38 vdc, 10 ma nominal

VOLTAGE-CONTROLLED SUBCARRIER OSCILLATORS

Subcarrier frequencies for Dr. Aggson's experiment were chosen arbitrarily, predicated on being low enough so that they could be filtered out of the magnetometer signal by normal methods, and yet high enough to yield reasonable carrier deviations that would assure acceptable signal-to-noise ratios. The initial selection of 14.5, 10.5, and 7.35 kc/s proved to be an acceptable supposition, and yielded SNR's with an adequate safety margin for the expected maximum slant range conditions.

MIXERS

A block diagram of the subcarrier and multiplex system is shown in Figure 10. Two mixer amplifiers were required. Mixer No. 1 provided isolation for the VCO multiplex from the magnetometer load, and allowed independent adjustment of the VCO multiplex level with respect to the magnetometer level. Prototype tests showed that this mixer was necessary to get sufficient drive to the transmitter when loaded by the magnetometer at the mixing resistor junction. The output of Mixer No. 1 was resistively added to the magnetometer output signal through a pair of 5.1K resistors. This combined signal was then amplified by Mixer No. 2 to become the modulation input to the transmitter.

Both mixers had a nominal flat frequency response within 0.5 db over the frequency range of 300 c/s to 100 kc/s. Although the magnetometer signal was somewhat higher in frequency, the roll-off at the 160 kc/s operating frequency was not excessive, as shown by the transmitter deviations curves (see Figures 2 through 9).

SUBCARRIER SYSTEM SETUP

Step-by-step procedures used for setting up and checking out the entire telemetry system are given in Appendix A. Serial numbers, frequencies used, and levels measured at principal points in the system, given for each payload, were used to aid in verifying a system's suitability for flight. In general, it was not feasible, nor should it have been necessary, to perform a complete check on the telemeter system when installed in the payload and when passing experimental data. Setup checks were performed under controlled conditions which simulated experimental data and required special connections which were not accessible when installed in the rack and connected to payload wiring. Flight readiness readings, obtained through the rf link, are also given in Appendix A.

ANTENNAS

The standard Apache telemetry system antenna is a four-element turnstile, with the antenna elements swept back at 45° to the longitudinal axis. A phasing harness inside the antenna section feeds the elements in space-phase quadrature to produce circular polarization. Details of the harness are shown schematically in Figure 11.

Right- or left-hand circular polarizations can be produced depending on how the harness is installed. By definition, a right-hand signal is one whose phase front rotates clockwise in the direction of propagation, identical to a right-hand screw thread. To produce right-hand circular polarization off the tail of the

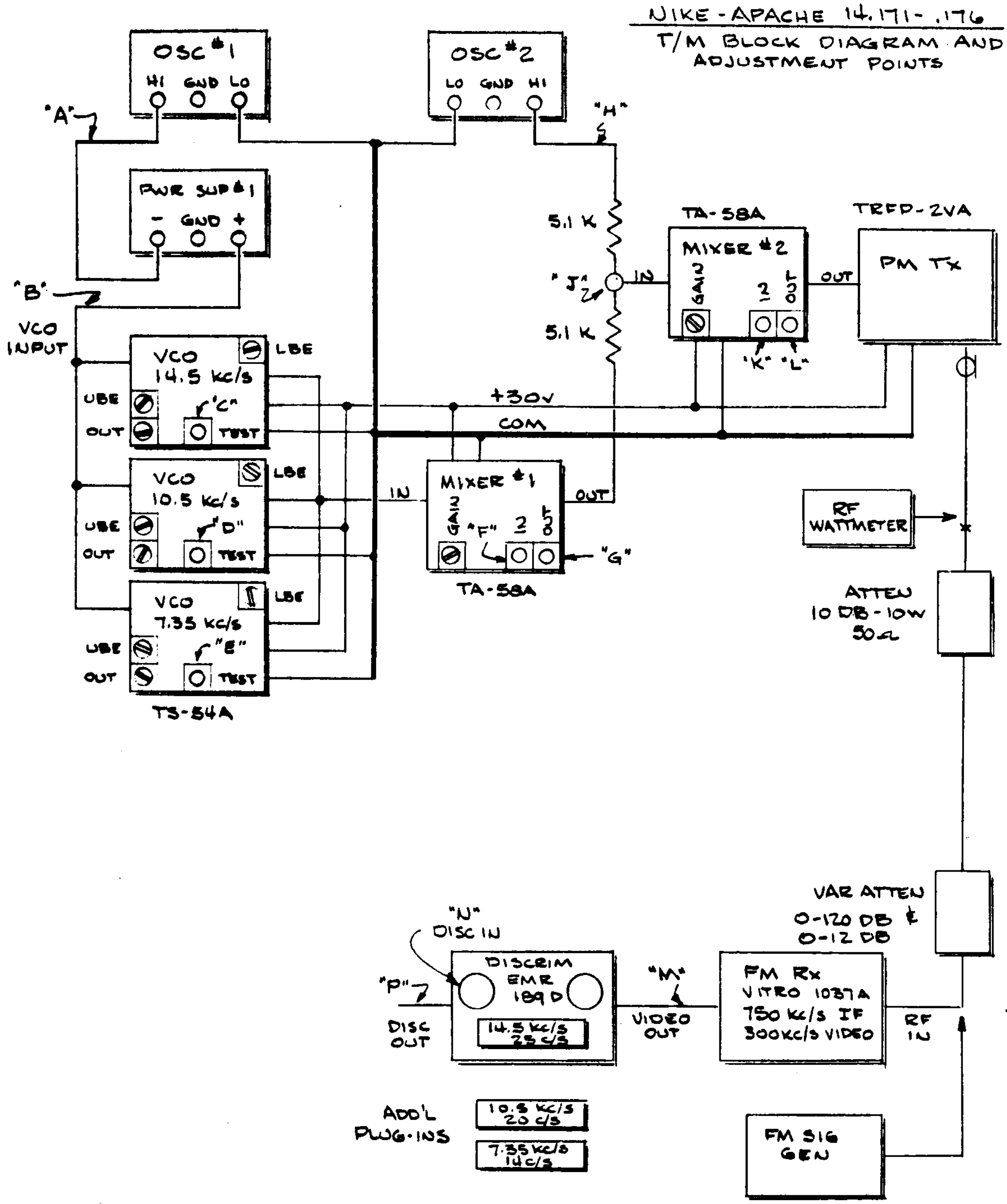

Figure 10. Telemetry System Block Diagram

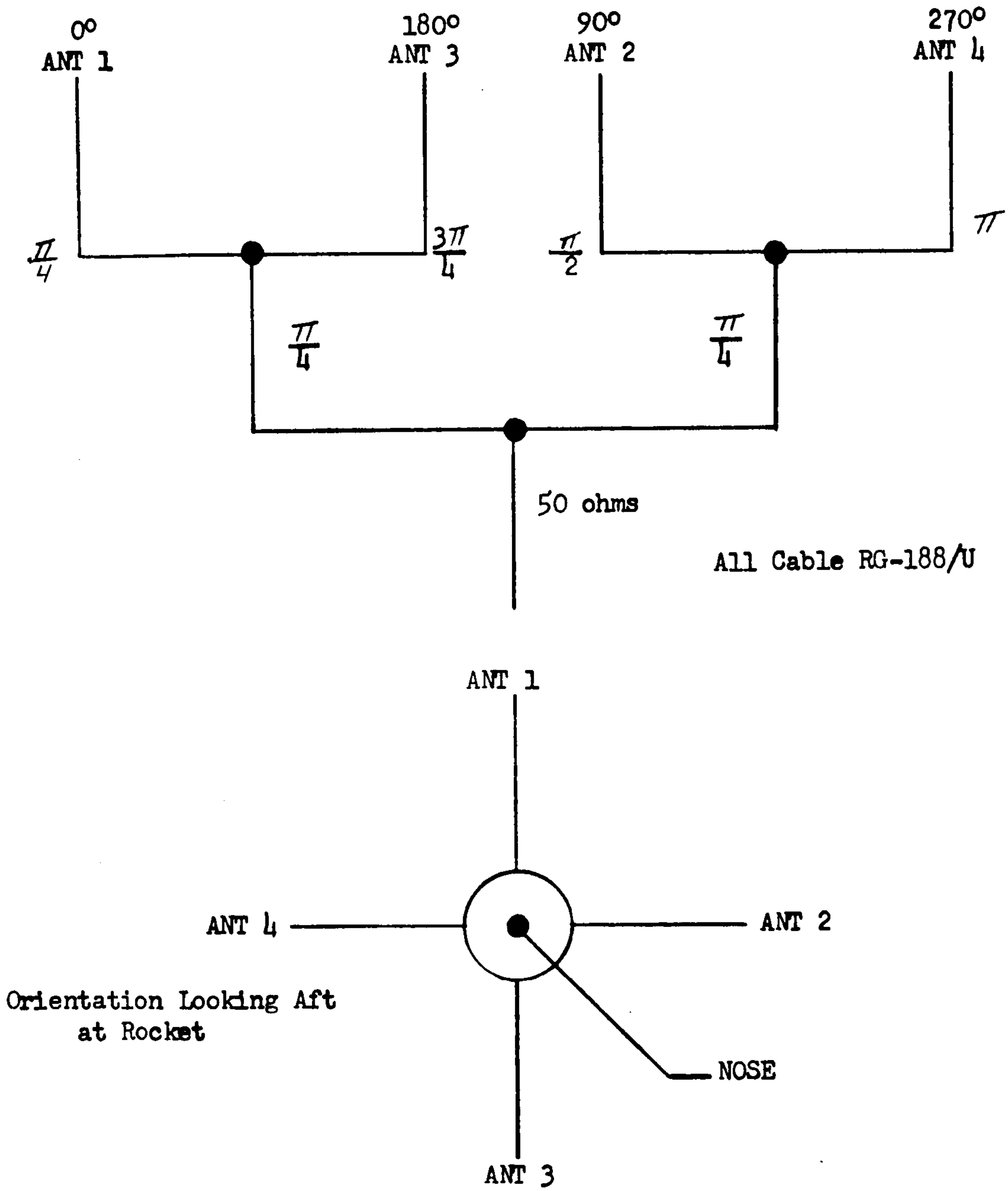

Figure 11. Turnstile Antenna Harness

rocket, the elements are fed in clockwise sequence looking aft by the progressively longer legs of the harness. These are numbered in order, No. 1 being the shortest, and No. 4 the longest. When looking forward into the open end of the antenna section, the numbers should increase counterclockwise. Right-hand circular helical antennas are standard for most telemetry ground stations, although some have both right- and left-handed antennas for diversity reception.

The advantages of a turnstile are that it is quite broad-banded and can be used over the frequency range of 230 to 240 mc/s without adjustment of its harness. Voltage standing wave ratio (VSWR) over this range is normally less than 1.2:1. Its radiation pattern to the rear is full and produces a gain of approximately +4 db over a dipole (+6.3 db above isotropic). No appreciable holes exist in the pattern for radiation well up the vehicle's side. A contour plot of a turnstile antenna, taken at 240.2 mc/s, is shown in Figure 12.

Two elements of the turnstile array were disconnected to provide probes for Dr. Aggson's experiment. With the addition of a new phasing harness, the remaining elements were converted to a linearly polarized dipole. This antenna system has all the characteristics of a dipole; its gain is +2.3 db above isotropic to the rear in the direction of its maximum radiation, with two deep nulls at right angles to the vehicle; its bandwidth is narrow; and its phasing harness must be adjusted to the operating frequency.

This antenna configuration has been flown many times in the past by other experimenters, with excellent results. Right- or left-hand helix ground antennas can be used with equally good results. A linear ground antenna will provide excellent vehicle spin data through signal strength variations.

SYSTEM SIGNAL-TO-NOISE RATIO

The procedure for predicting the performance of a telemetry system is to add all the component gains and losses, expressed in db, and determine from the resultant whether there is enough signal over the threshold noise level to produce a useful measurement. Parameters which must be included in this analysis are: (1) transmitter power (expressed as dbm, with respect to 1 milliwatt), (2) vehicle antenna gain (with respect to isotropic), (3) transmission path loss, and (4) receiving antenna gain (with respect to isotropic).

Other system characteristics involving receiver input impedance, receiver input noise figure, receiver bandwidth, and bandwidth utilization should also be specified to complete the overall analysis. However, these latter parameters were fixed by ground station

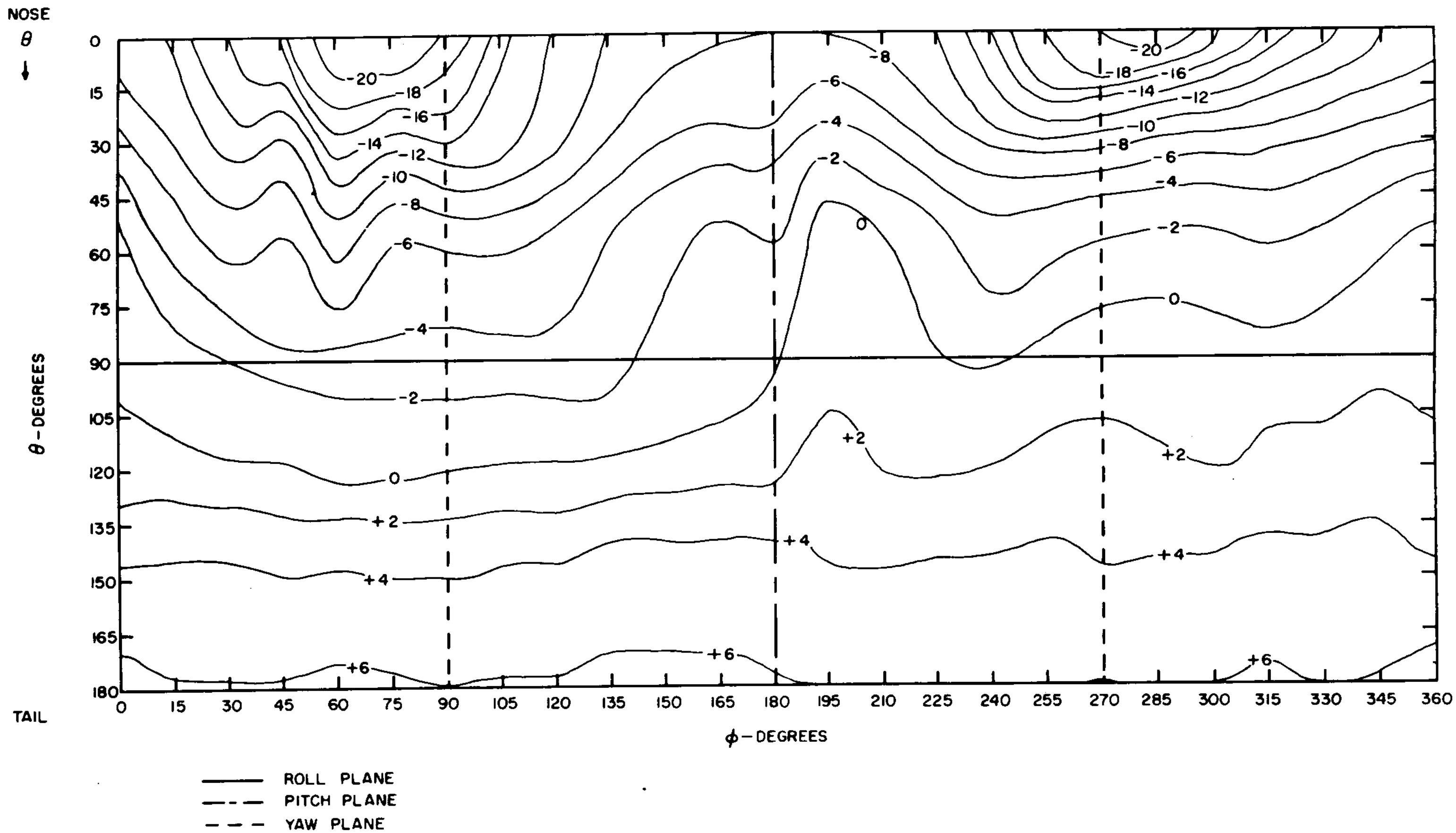

Figure 12. Turnstile Antenna Countour Plot

design and not subject to appreciable variation. One measurement on the system will, therefore, determine its operational efficiency, to which vehicle-dependent functions can be added to determine overall performance under specific conditions.

This procedure was followed in developing the SNR curve for 160 kc/s magnetometer data shown in Figure 13. Parameters which were normalized for this curve were:

Transmitter RF Power	2.5 watts
Transmitter Deviation	±125 kc/s
Receiver Bandwidth	750 kc/s
Receiver Input Noise Figure	+7 db

A path loss nomograph, calculated for an rf link on 231.4 mc/s, is also included.

These data can be used to find system SNR at any point in the trajectory, as follows:

a. Determine the path attenuation for the slant range of interest.

b. Determine vehicle antenna gain over isotropic.

c. Determine ground station antenna gain over isotropic.

d. For a vehicle-ground station system, normalized as indicated above, the calculations are complete. Add the numbers algebraically to determine the system threshold.

e. From the curve in Figure 13, find the magnetometer SNR corresponding to this value. Signal level input to the receiver can also be obtained.

f. If the system is not normalized, use the small nomographs to correct for variations in the capability level.

As an example, a normal system might be calculated as follows:

a.	Path attenuation at 100 miles	-124 db
b.	Vehicle antenna gain (turnstile)	+ 4
c.	Ground station antenna gain (8-turn helix)	+ 10
d.	Capability	-110 db
e.	Magnetometer SNR	+ 28 db

SNR's for Dr. Aggson's data are the difference between the system capability determined above, and the system threshold measured and recorded in Appendix A.

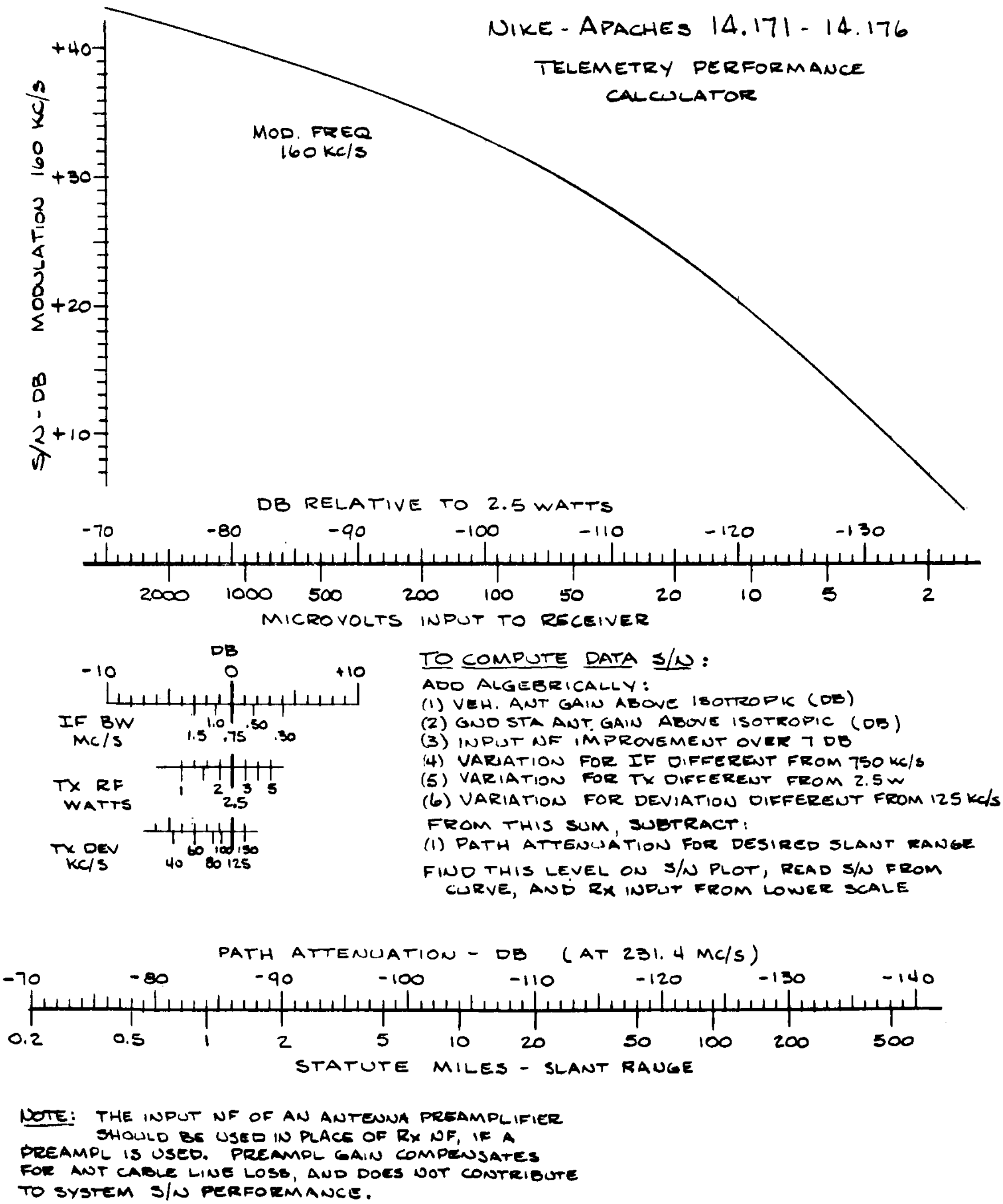

Figure 13. Telemetry Performance Calculator

Thus, a system with a VCO threshold of 129 db and a capability of -110 db would have a 19 db SNR at apogee for Dr. Aggson's data.

CONCLUSION

The conclusion of this report is, in reality, the successful flights of Nike Apache payloads 14.171 GE through 14.176 GE. Information pertaining to these flights are contained in Report on Mobile Launch Expedition Number 1, X-671-65-166.

APPENDIX A

SETUP AND CHECKOUT MEASUREMENTS

TELEMETER COMPONENTS			14.171	14.172	14.173	14.174	14.175	14.176
COMPONENT	MFGR	MODEL		SERIAL NUMBER				
Transmitter	Vector	TRFP-2VA	459	462	457	460	455	453
14.5 KC/S VCO	Vector	TS54A	1878-25	1995-25	1991-25	1883-25	1881-25	1879-25
10.5 KC/S VCO	Vector	TS54A	1696-5	1691-5	1989-25	1986-25	1876-25	1692-25
7.35 KC/S VCO	Vector	TS54A	1869-25	1686-5	1865-25	1687-5	1867-25	1869-25
Mixer No. 1	Vector	TA58A	955	946	903	926	841	944
Mixer No. 2	Vector	TA58A	966	952	971	939	957	932

PREPARATORY SETUP Set up telemetry components and measuring eqüipment as given in Figure 9. Install test cable. Use a X10 probe on CRO to minimize loading. Carefully adjust probe frequency compensation. Turn on external power, adjust to 30V. Record voltage and current. All readings referenced to power common.

Power Supply Volts (+30.0)	30.0	30.0	30.0	30.0	30.0	30.0
Amps	0.83	0.85	0.85	0.73	0.72	0.79

VCO BANDEDGE ADJUSTMENT Allow 5-minute warmeup. Set oscillator no. 1 output "A" to zero and short out terminals. Set power supply no. 1 output "B" to zero and short out terminals. Adjust LBE potentiometer on all VCOs to give low bandedge frequency as measured by counter, at test points "C", "D", and "E". Remove short from power supply no. 1 and set output "B" to +5.00 vdc. Adjust UBE potentiometers on all VCOs to give upper bandedge frequency, as measured by counter, at test points "C", "D", and "E". Alternately check LBE and UBE. Readjust as necessary since there is interaction between potentiometers. Record final LBE and UBE frequencies below.

14.5 KC/S LBE (13,412)	13,413	13,411	13,414	13,412	13,412	13,412
10.5 KC/S LBE (9712)	9714	9712	9713	9713	9712	9712
7.35 KC/S LBE (6799)	6799	6797	6800	6798	6799	6801
14.5 KC/S UBE (15,588)	15,589	15,587	15,589	15,587	15,588	15,588
10.5 KC/S UBE (11,288)	11,289	11,285	11,288	11,286	11,288	11,288
7.35 KC/S UBE (7901)	7901	7899	7900	7901	7901	7901

Set power supply no. 1 output "B" to +2.50 vdc. Measure VCO center frequency at test points "C", "D", and "E" with counter and record.

14.5 KC/S Center Frequency	14,502	14,501	14,499	14,498	14,498	14,498
10.5 KC/S Center Frequency	10,502	10,498	10,499	10,498	10,498	10,498
7.35 KC/S Center Frequency	7349	7348	7348	7349	7349	7349

Set oscillator no. 2 output "H" to zero. Adjust VCO output voltage at test points "C", "D", and "E" to preliminary values given below, using CRO.

	14.171	14.172	14.173	14.174	14.175	14.176
14.5 KC/S "C" (2.6V peak-to-peak)	3.1	2.9	2.4	2.9	2.65	2.7
10.5 KC/S "D" (3.4V peak-to-peak)	3.9	3.7	3.15	3.6	3.45	3.4
7.35 KC/S "E" (3.9V peak-to-peak)	4.4	4.7	3.9	4.9	3.9	3.9

Measure mixer no. 1 input "F". Adjust mixer no. 1 gain potentiometer to give preliminary output "G" below. Use CRO.

Mixer no. 1 IN "F" (1.5V peak-to-peak)	1.6	1.56	1.35	1.6	1.5	1.3
Mixer no. 1 OUT "G" (3.9V peak-to-peak)	4.5	4.2	3.85	4.2	3.9	3.8

Preliminary adjustment of VCOs and mixer no. 1 has been completed. Final adjustments will be made later using the ground station.

<u>TRANSMITTER DEVIATION ADJUSTMENT</u> Connect FM signal generator to FM receiver's RF input. Set the signal generator to: MOD-FM; MOD FREQ-INT AT 30 KC/S; Deviation ±125 KC/S; RF frequency- 231.4 MC/S; RF OUT-1000 mv. Tune the receiver. Set video filter to 300 KC/S. Adjust the video output "M" to 5.0V peak-to-peak using the CRO. Do <u>NOT</u> change these settings for all other readings.

Disconnect the receiver from the signal generator and reconnect to attenuated RF cable from the transmitter. Set variable attenuator to 50 db.

Set oscillator no. 2 to 160 KC/S. Unshort and adjust oscillator no. 2 output "H" to 5.0V peak-to-peak. Adjust mixer no. 2 gain to give 5.0V peak-to-peak on receiver output "M", using CRO. Fuzz on 160 KC/S signal is VCO multiplex. Adjust mixer no. 2 gain to split fuzz. Measure the following:

Oscillator No. 2 OUT "H" (5.0V peak-to-peak)	5.0	5.0	5.0	5.0	5.0	5.0
Mixer No. 2 IN "K" (3.7V peak-to-peak)	3.55	3.7	3.4	3.6	3.9	3.6
Mixer No. 2 OUT "L" (8.0V peak-to-peak)	8.8	8.0	8.4	4.0	8.0	8.5
Receiver Video OUT "M" (5.0V peak-to-peak)	5.0	5.0	5.0	5.0	5.0	5.0

Check and record discriminator input "N" for each VCO by inserting the proper discriminator channel selector and LPOF. Note nominal values. If discriminator input "N" voltages are all off in the same direction, adjust mixer no. 1 gain. Trim to nominal values with VCO output potentiometers.

14.5 KC/S Discriminator IN "N" (0.07V RMS)	0.07	0.07	0.07	0.070	0.064	0.07
10.5 KC/S Discriminator IN "N" (0.06V RMS)	0.06	0.06	0.06	0.065	0.062	0.06
7.35 KC/S Discriminator IN "N" (0.05V RMS)	0.05	0.05	0.05	0.053	0.049	0.05

Remeasure VCO test points "C", "D", and "E", mixer no. 1 IN "F", and OUT "G". Record as final readings above.

THRESHOLD SIGNAL LEVELS Set oscillator no. 1 to 12 C/S. Remove short and adjust oscillator no. 1 output "A" to 5.0V peak-to-peak using a CRO. Connect the CRO to discriminator output "P". Discriminator output gain is immaterial. Install 14.5 KC/S channel selector. Observe 12 C/S discriminator output as RF attenuation to receiver is increased. Record total attenuation when distortion becomes severe. Repeat with other channel selectors installed.

	14.171	14.172	14.173	14.174	14.175	14.176
14.5 KC/S channel selector (-129 db)	127	129	129	129	130	129
10.5 KC/S channel selector (-129 db)	127	130	129	130	131	129
7.35 KC/S channel selector (-129 db)	127	129	129	130	131	129

Connect CRO and VTVM to receiver video output "M". Set receiver RF attenuation to total db indicated and make measurements.

		14.171		14.172		14.173		14.174		14.175		14.176		
DB	OSC NO.2	VTVM		VTVM		VTVM		VTVM		VTVM		VTVM		
	V P-P	V RMS	DB	V RMS	DB	V RMS	DB	V RMS	DB	V RMS	DB	V RMS	DB	
50	5.0	1.7	+6.8	1.68	+6.8	1.55	-3.95	1.64	+6.5			1.64	-3.5	S + N
50	0	.098	-1.8	.105	-17.4	.093	-8.5	.092	-18.6			.105	-7.3	N
SNR at 50 DB														
130	5.0	1.7	+6.8	1.85	+7.6	1.57	-3.9	1.66	+6.6	2.25	+8.4	1.65	-3.4	S + N
130	0	.78	0	1.3	4.5	.49	-3.8	.55	-2.9	1.26	+4.5	.85	+0.8	N
SNR at 130 DB														

$$\text{Signal (volts)} = \sqrt{(S + N)^2 - N^2}$$

Turn telemetry off. Disconnect transmitter from attenuator and reconnect to wattmeter. Turn telemetry on. Measure RF power output.

	14.171	14.172	14.173	14.174	14.175	14.176
RF Power Output (watts)	3.35	5+	4.95	4.9	3.85	3.2

Turn oscillator no. 2 off. Measure receiver video output "M" using CRO.

APPENDIX B

SETUP AND CHECKOUT NOTES

Appendix B includes a series of comments useful in determining reasons for performing the operations in the order given, and the consequences and explanations for doing these in the manner prescribed.

When starting from an initial setup, or if a VCO has been replaced on a previously adjusted system, the first operation is to adjust the VCO bandedges to their prescribed values. Equipment for providing stable input voltages of 0, +2.50, and +5.00 vdc is required. There is some interaction between the low bandedge (LBE) and upper bandedge (UBE) potentiometers, so that several alternate adjustments may be necessary. Start with the LBE adjustment first, since it has the larger effect on final settings. A counter, connected to the VCO test point, can accurately count the frequency of that particular VCO even though the VCO is connected to the multiplex. The VCO test point is taken out at high level, and isolated from the VCO multiplex by a 47K resistor.

VCO output voltages, measured at the test point, are then set to the preliminary values given in parenthesis (see Appendix A page 2 for each flight). These levels were derived from the prototype system, and are subject to final adjustment to compensate for overall system variations.

All readings are given as peak-to-peak levels, and are determined from the face of a CRO. Because of high frequency loading, an isolation probe should be used at all times. Make sure the probe is exactly compensated to the CRO being used. Errors, as great as 50%, were noted during prototype testing from a probe that was only slightly out of adjustment.

After the VCO's have been set to their preliminary output levels, Mixer No. 1 output is set to its preliminary value. Input and output voltages can be measured directly at the appropriate test points on the mixer amplifier. Adjustments up to this point have been classed "preliminary", since they have been made without reference to the transmitter's actual modulation response characteristics. Final settings will be made after Mixer No. 2 is adjusted, and after the system's performance has been measured into a ground station. All further adjustments are made through the rf link while observing indications from the ground station.

Sounding Rocket Instrumentation Section uses 5 volts peak-to-peak video output for a ±125 kc/s carrier deviation as a standard receiver video output reference. This usually is set at a modulating frequency of 30 kc/s, although response is uniform until significant sidebands get beyond the IF bandwidth. For these tests, the receiver should have a 750 kc/s IF strip, and its video low pass filter should be set for a cutoff frequency just above the expected 160 kc/s magnetometer frequency, usually 300 kc/s.

The transmitter is hard-wired directly to the receiver through suitable attenuators, to preclude errorneous readings from high VSWR's on mismatched antennas, rf reflections within the test enclosure, and varying signal strengths as personnel work around the payload. A 10-watt, 10-db attenuator should be placed near the transmitter and ahead of the variable attenuators which can handle only 1/2-watt. RF cable must be 50 ohms. Total attenuation is adjusted to give a good, workable receiver input level, in the vicinity of 1000 microvolts. Video output will remain constant as long as the IF is saturated, normally for input levels of 30 microvolts and higher.

After this setup is made, an oscillator is connected to the magnetometer signal input, set to a frequency of 160 kc/s, and adjusted to give 5 volts peak-to-peak output (under the 5.1K load). Because the VCO's are multiplexed on this signal, the scope presentation will appear somewhat fuzzy. With the sweep set to show two or three cycles of the 160 kc/s signal, adjust Mixer No. 2 so that 5 volts peak-to-peak splits the fuzz. The transmitter has now been adjusted to give ±125 kc/s deviation for an expected magnetometer output signal of 5 volts peak-to-peak at 160 kc/s. On the ground, and at other latitudes, the actual magnetometer signal may be different from 160 kc/s. Some small variations away from ±125 kc/s deviation can be expected as a result of these conditions, the magnitude of which can be correlated from the deviation sensitivity curves for that particular transmitter. Modulation from the VCO multiplex causes the instantaneous peak deviation to be about 10 to 15 percent greater than ±125 kc/s, well within the limits of the transmitter.

Most telemetry receivers have built-in deviation meters. They are average reading voltmeters whose scales are calibrated to read peak deviation. They will read correctly <u>only</u> on single frequency modulation, usually below 50 kc/s, and can <u>not</u> properly measure a multiplex signal. Disregard their readings entirely.

Performance of the VCO system can be checked by measuring the on-channel voltage of each VCO at the discriminator input. Nominal values derived from the prototype setup are given in the check sheet (Appendix A). These readings are taken with the VCO's held at the center frequency by a +2.50 vdc signal on their inputs. Because of the frequency response of the discriminator channel selector bandpass filters, the on-channel reading can vary down to 70% (-3 db) of the specified value at the bandedges. In checking VCO levels in preparation for flight, the position in the band must be considered in evaluating these readings.

On-channel voltage readings were obtained from SNR measurements on the prototype package, operating under simulated flight conditions. A 12 c/s input signal, applied to each VCO, represented the highest spin-modulated data signal expected from Dr. Aggson's experiment. A ground station record of these 12 c/s data signals was made as the rf attenuation in the hard-wire line, between transmitter and receiver, was increased until appreciable signal deterioration occurred. Discriminator low pass filters were 25, 20, and 14 c/s for the 14.5, 10.5, and 7.35 kc/s channels, respectively. These are much lower than standard and were selected to take advantage of the maximum 12 c/s data rate to improve overall system SNR. Ground stations cutting real-time records during flight should be checked to see that this variation is included.

Figure B-1 (8 sheets) show the data degradation as the rf attenuation was progressively increased. Records of -120 and -130 db attenuation show good, clean data. At -132 db, a small amount of peak amplitude variation is present, degrading to poor quality at -134 db, and useless ramblings beyond -137 db. This system would be considered to have a threshold at -132 db.

This test was made on all payloads and served as the basis for setting the three VCO channels to the same SNR and setting the threshold on Dr. Aggson's experiment to a prescribed value. Individual VCO output voltages were readjusted from their preliminary values, as required, to make all channels drop out uniformly. Then Mixer No. 1 was readjusted to bring the threshold to between -127 db and -133 db. These adjustments must be made through the rf link since the system performance depends on the transmitter low frequency modulation sensitivity and rf power output. Ground station parameters also enter into this evaluation, but are not a variable.

SNR for the 160 kc/s magnetometer signal was measured by a VTVM connected to the receiver video output for the two conditions of signal plus noise, and noise alone (160 kc/s modulation removed), as the rf attenuation was gradually increased. The VTVM was a HP 400 LR and read the average value of the input signal, although calibrated in RMS values. While not providing the accuracy of a true-rms meter, the measurements are considered a first approximation to SNR. Magnetometer SNR was calculated from these two readings as:

$$\mathrm{SNR} = \frac{(S + N)^2 - N^2}{N} \qquad \text{(expressed in db)}$$

A plot of the prototype system is given in Figure 13. Even at -135 db attenuation, the 160 kc/s could be determined visually from random receiver nose. A narrow tracking filter could improve the SNR even further.

SNR's are a "black art" at best. It does not pay to try working a system down to its theoretical limit. Too many ill-defined parameters can dissolve the reserve, the most important of which are over-optimistic equipment specifications and sub-standard performance. All equipment used for these measurements were quality instruments, but not checked to specifications. They were probably representative of equipment found in a well-maintained ground station.

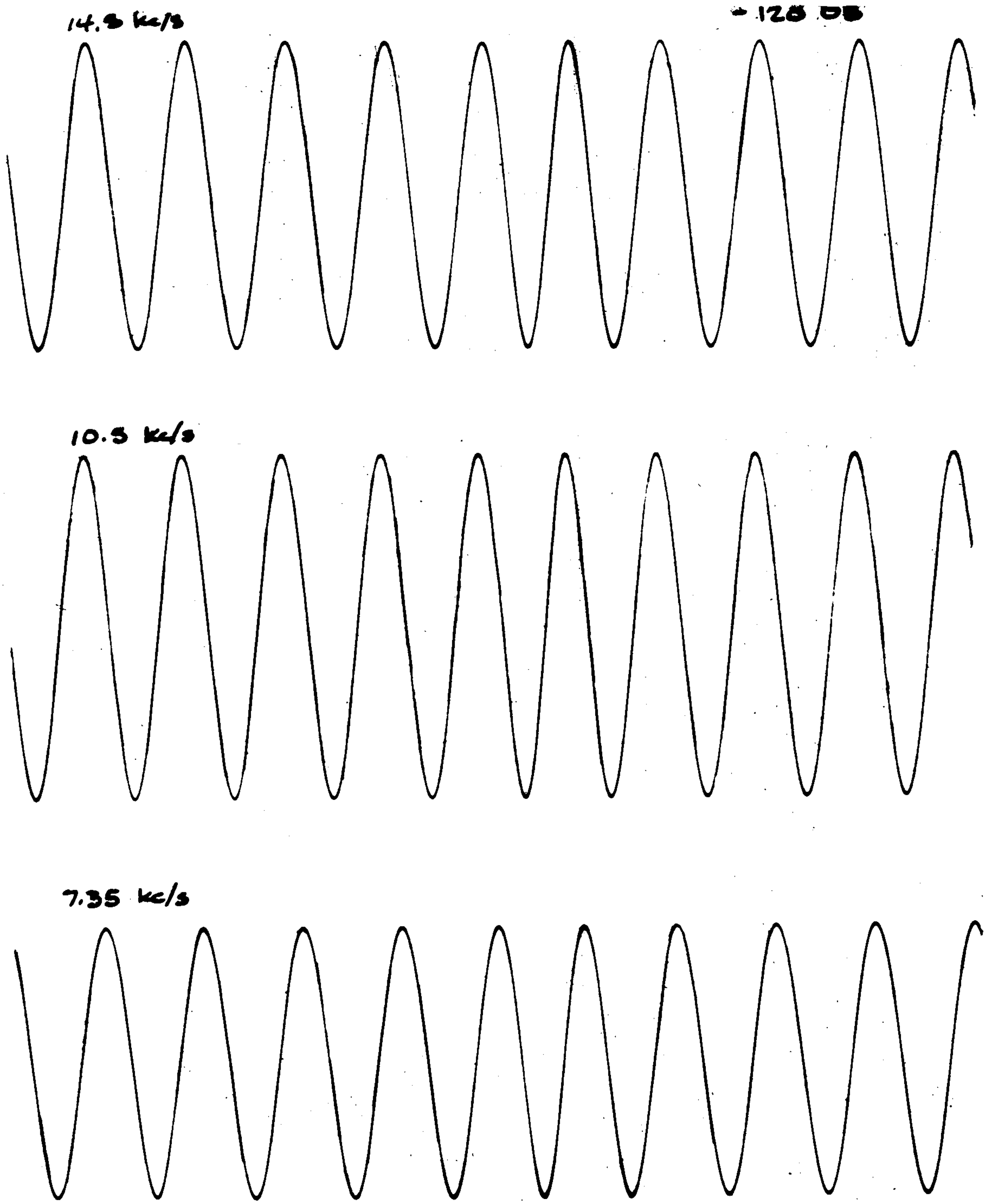

Figure B-1. Data Degradation with Increasing RF Attenuation (Sheet 1 of 8)

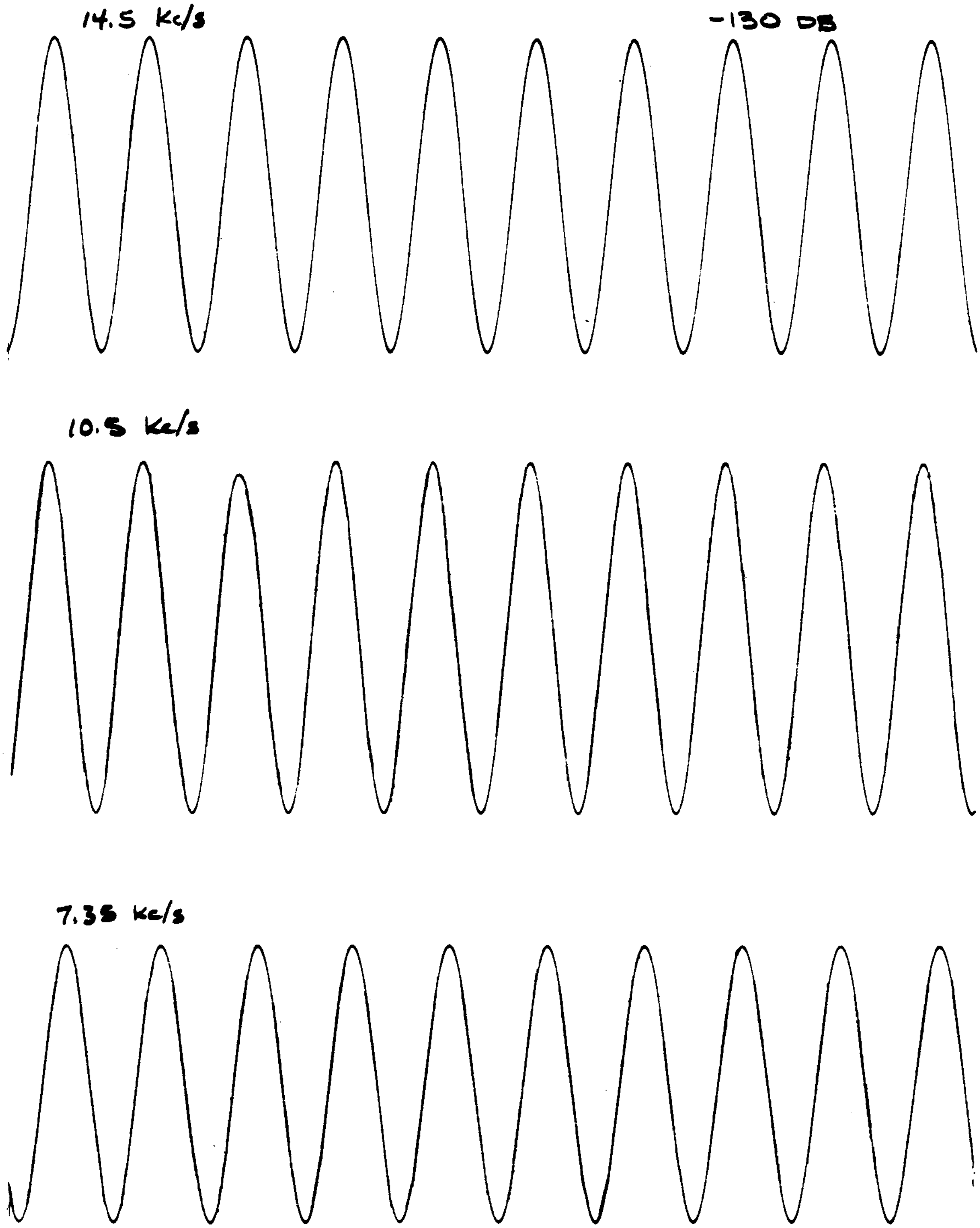

Figure B-1. Data Degradation with Increasing RF Attenuation (Sheet 2 of 8)

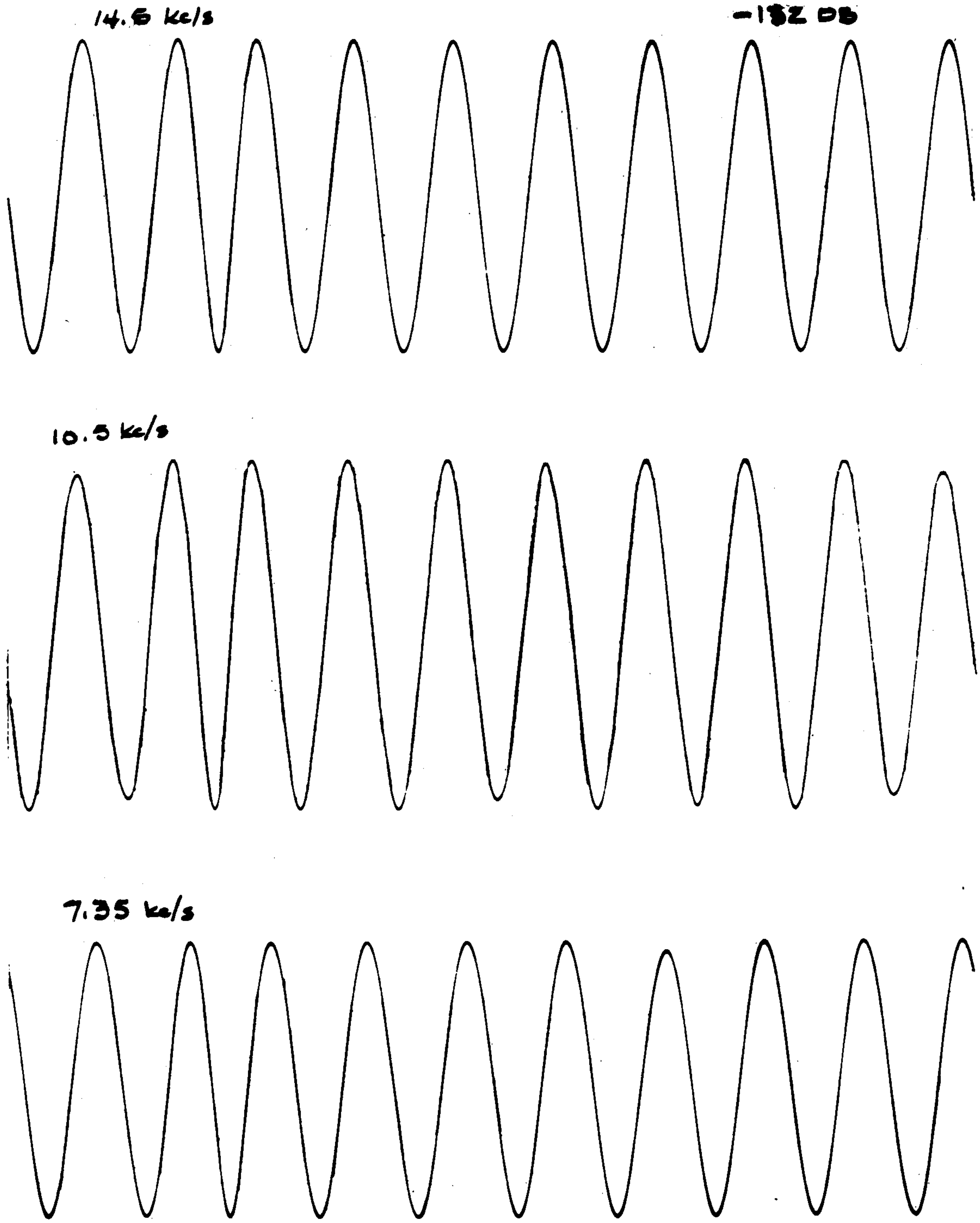

Figure B-1. Data Degradation with Increasing RF Attenuation (Sheet 3 of 8)

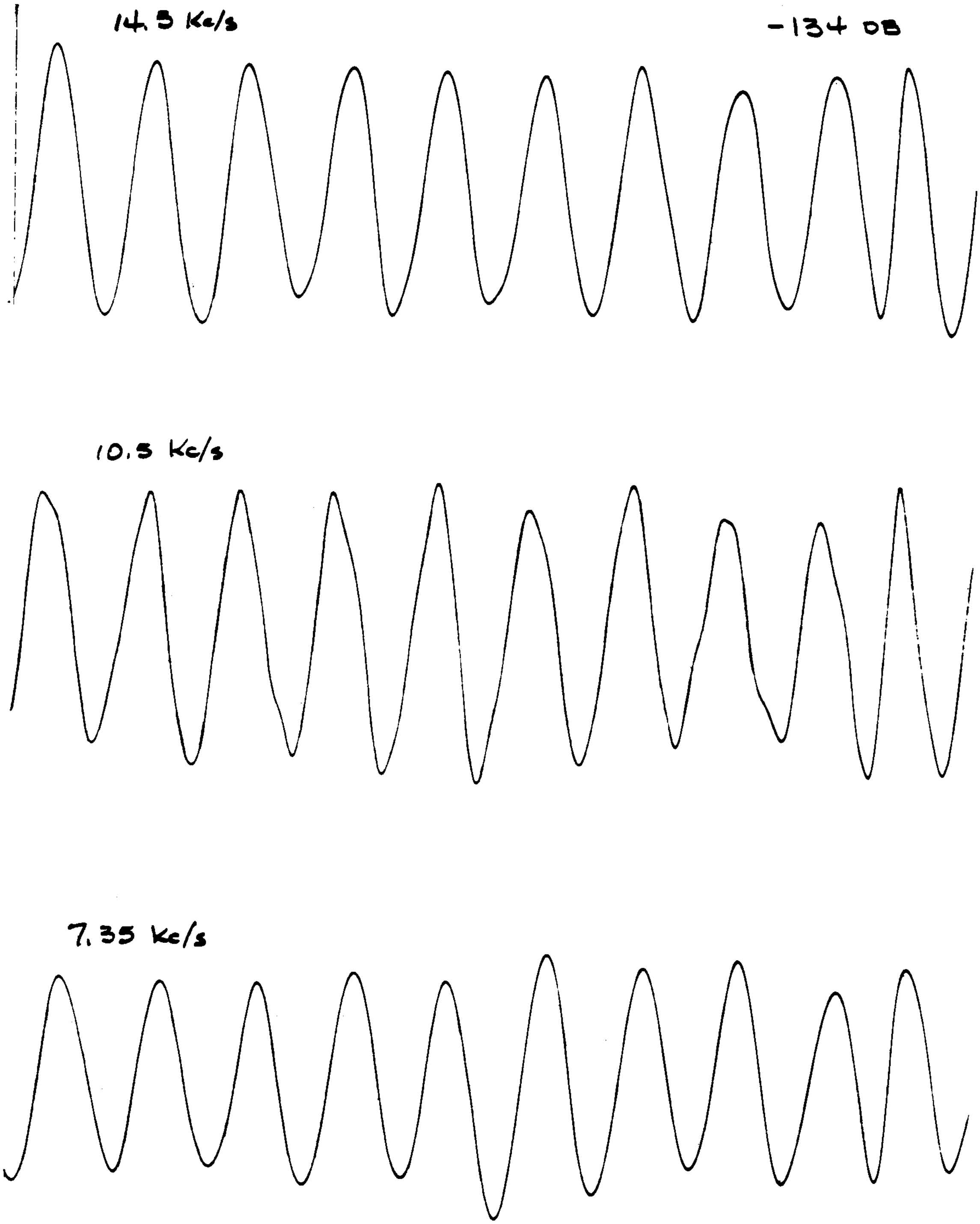

Figure B-1. Data Degradation with Increasing RF Attenuation (Sheet 4 of 8)

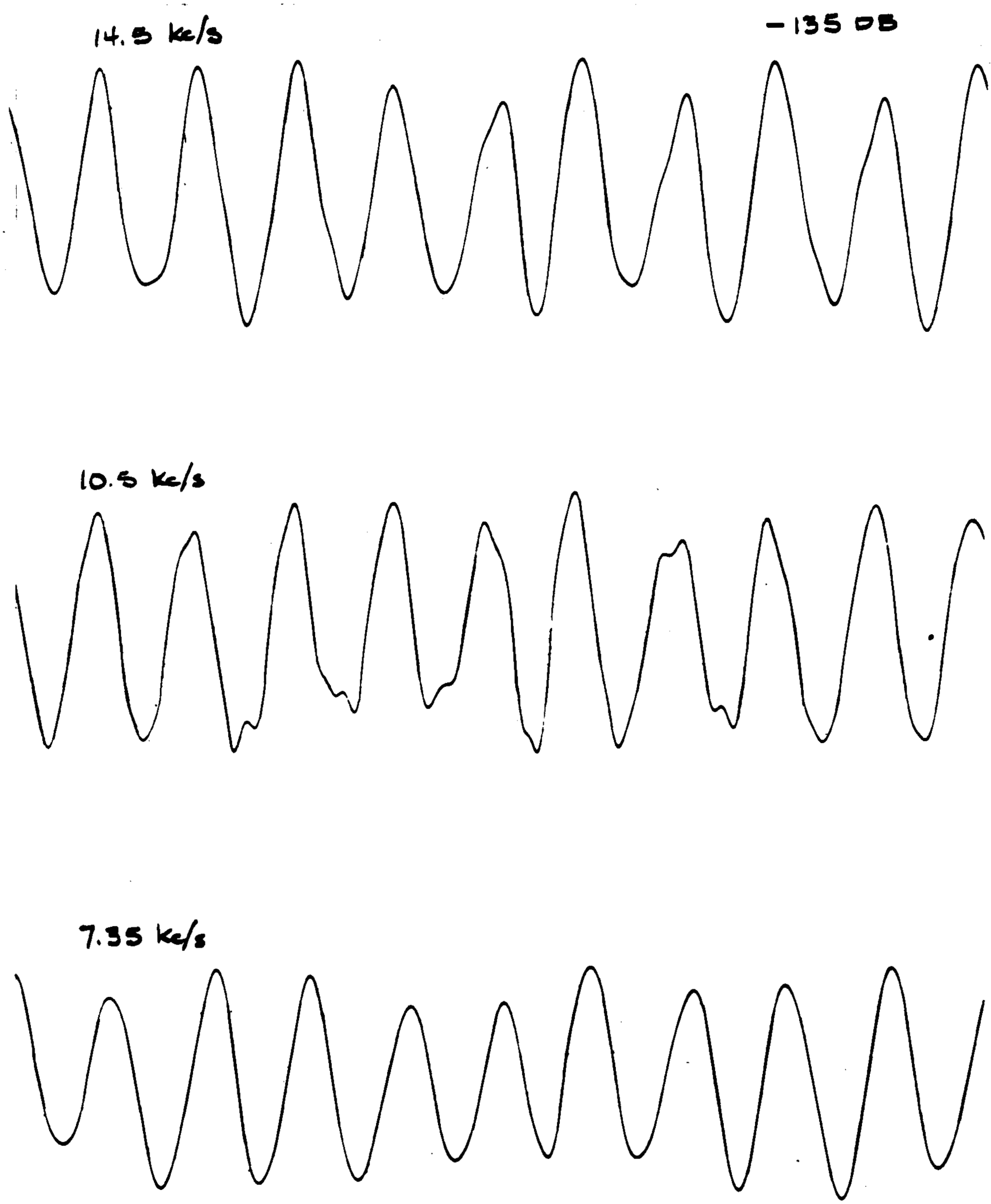

Figure B-1. Data Degradation with Increasing RF Attenuation (Sheet 5 of 8)

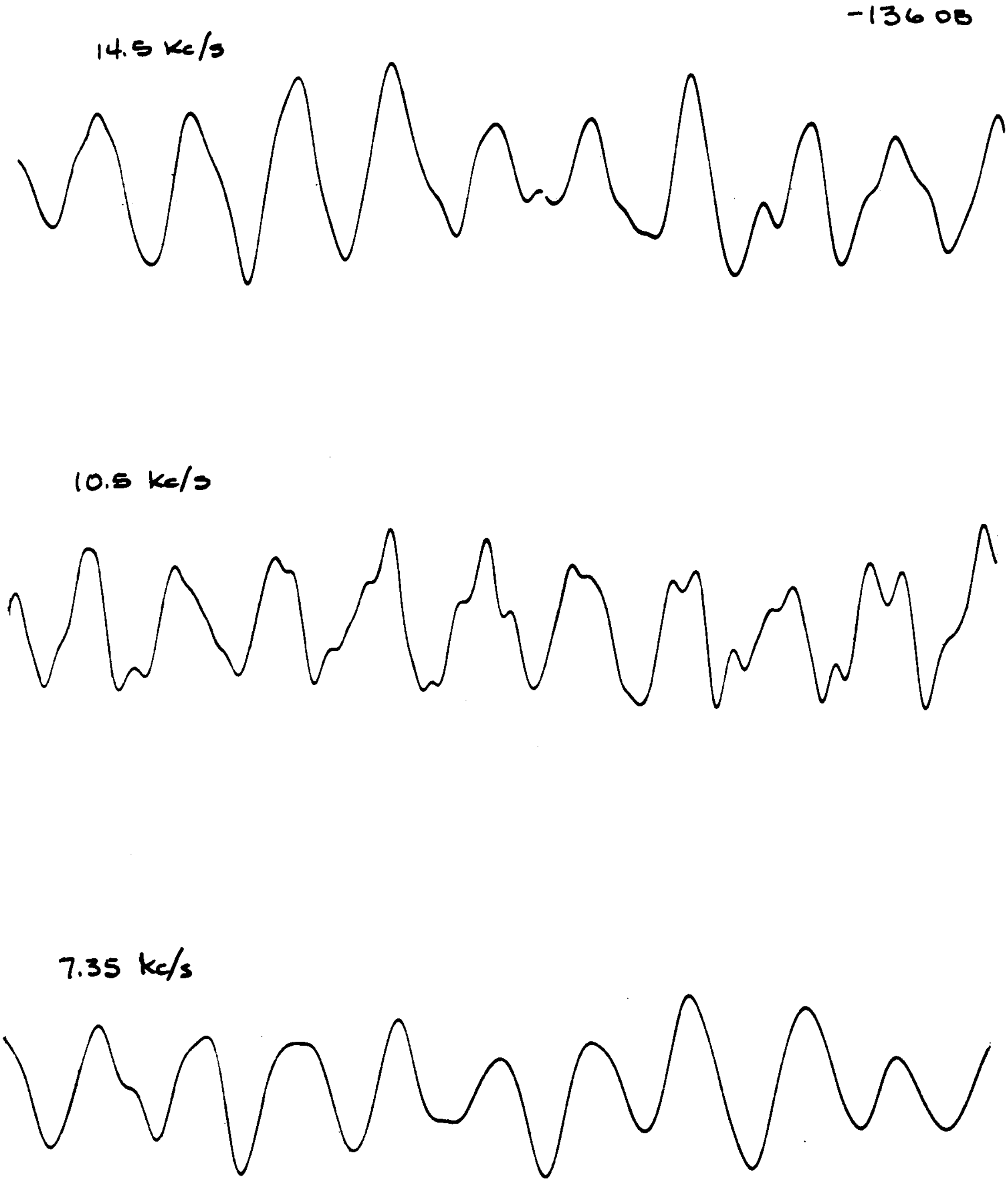

Figure B-1. Data Degradation with Increasing RF Attenuation (Sheet 6 of 8)

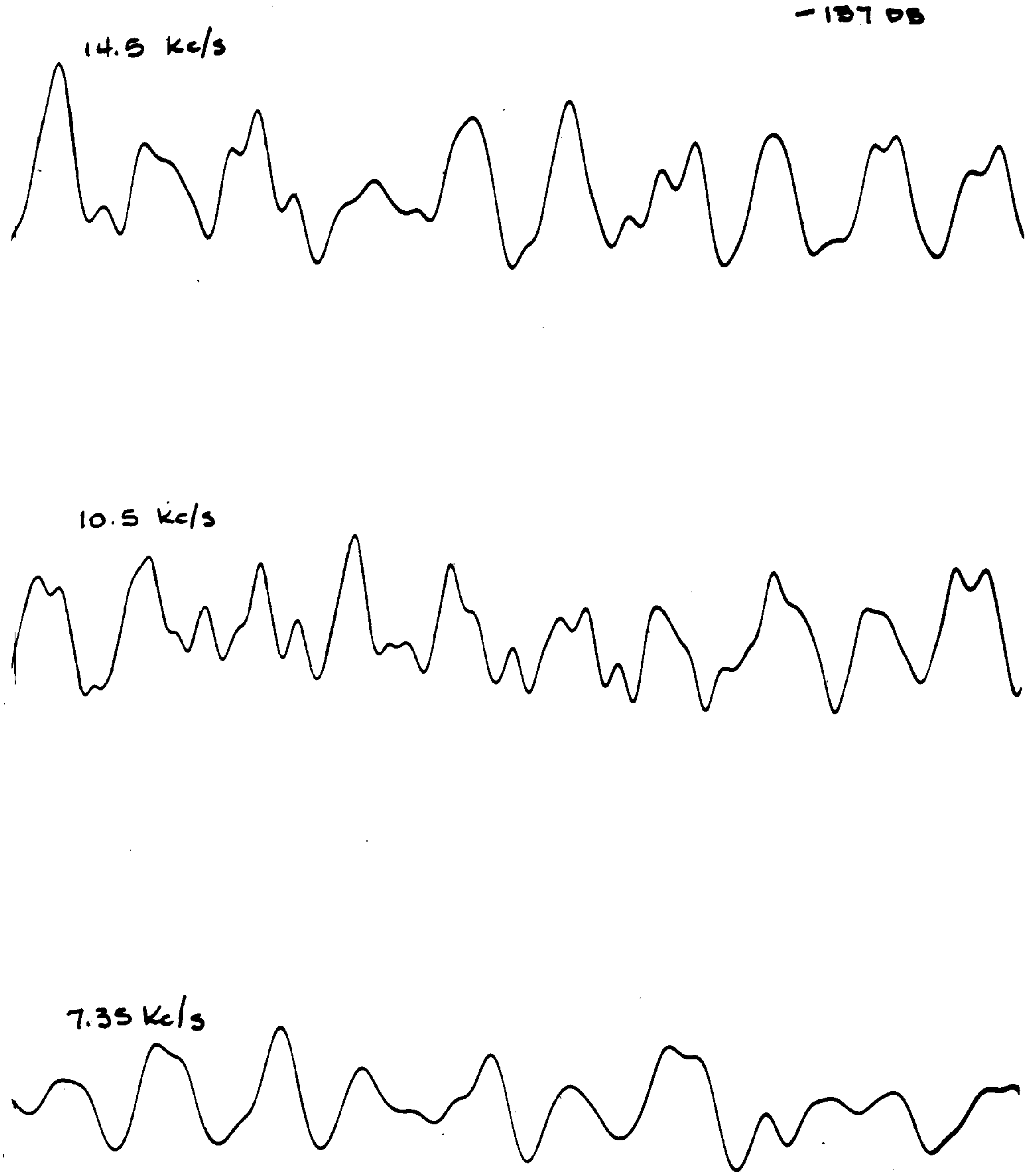

Figure B-1. Data Degradation with Increasing RF Attenuation (Sheet 7 of 8)

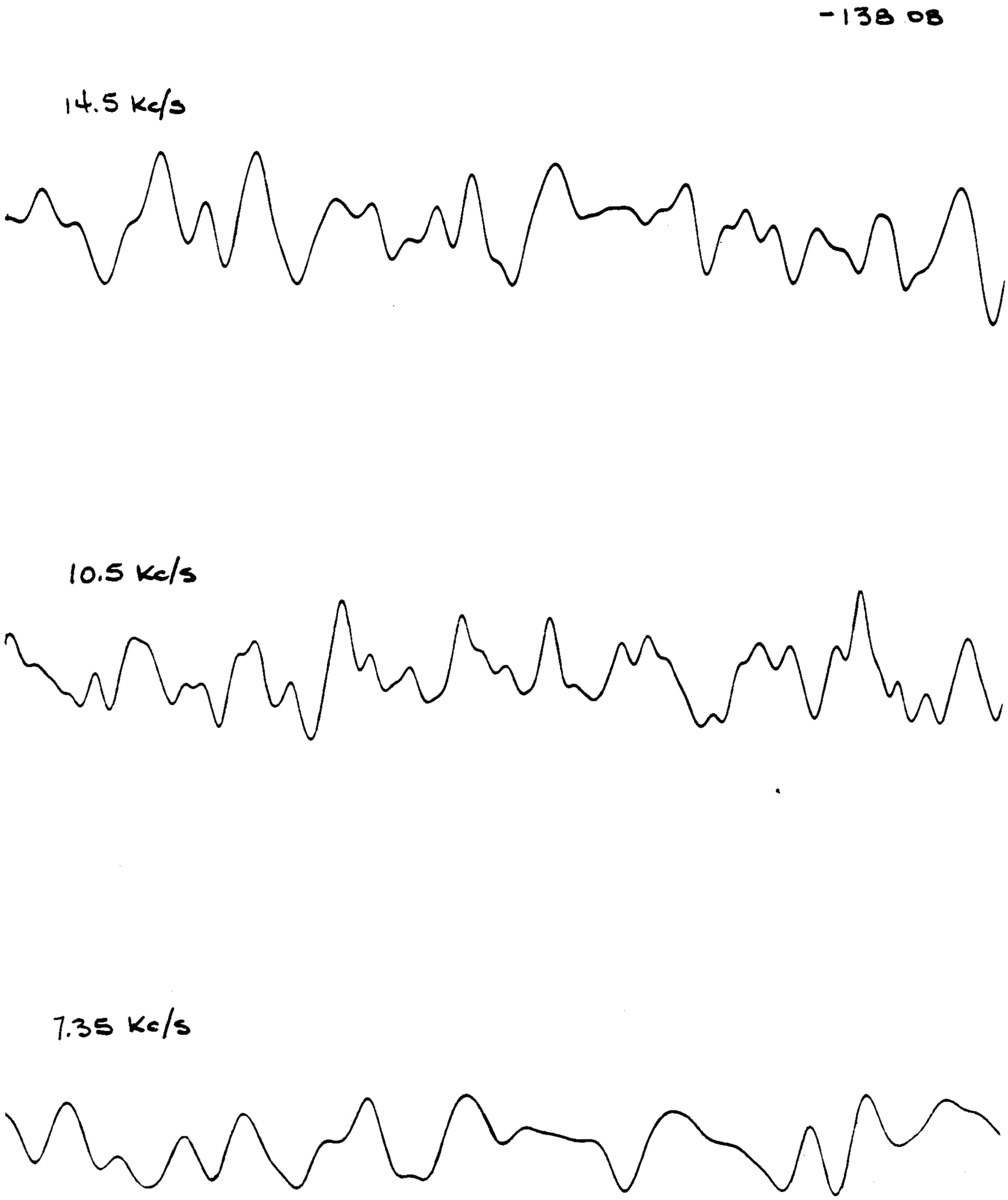

Figure B-1. Data Degradation with Increasing RF Attenuation (Sheet 8 of 8)